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Advanced WLAN Site Survey

Metropolia University of Applied Sciences

Bachelor of Engineering

Degree Programme

Thesis

27.03.2018

Metropolia

Author Title Number of Pages Date	Kabindra Ranabhat Advanced WLAN Site Survey 50 pages 21 August 2017
Degree	Bachelor of Engineering
Degree Program	Name of the degree program
Professional Major	Networking
Instructors	Senior Lecturer Jukka Louhelainen

This thesis was carried out in Meropolia Leppävaara campus. This main purpose of this thesis was to explore WLAN in connection with a site survey and to improve user experience on the campus with wireless network modeling by using the Ekahau Site Survey tool kit. The latest features of ESS tool made the survey results close to perfection and results were used to make necessary network troubleshooting and optimization.

The theory part of this Bachelor's thesis is mainly based on Literature sources. This thesis briefly presents all the measurements taken from the basement area of Metropolia campus where all the Cisco Labs are located and also introduces detail information on latest network standards, designs, features and specifications.

Experience gained from this thesis project showed that there are several benefits of having a smart network infrastructure. It is necessary to optimize the network problem sooner than later and remain up to date with the network standards in this competitive technological world.

Keywords	Advanced WLAN Site Survey

Metropolia

Contents

List of Abbreviations

ESS	Ekahau Site Survey
WLAN	Wireless Local Area Network.
DHCP	Dynamic Host Configuration Protocol
AD	Active Directory
VoIP	Voice over Internet Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCP/UDP	Transmission Control Protocol/User Datagram Protocol
SSID	Service Set Identifier
VLAN	Virtual Local Area Network
MBPS	Megabits Per Second
IOT	Internet of Things
IEEE	Institute of Electrical and Electronics Engineers
NIC	Network Interference Controller
USB	Universal Serial Bus
RF	Radio Frequency
AP	Access Point
SNR	Signal to Noise Ratio
DR	Data Rate
SIG	Bluetooth Special Interest Group
ISM	Industry Scientific and Medical
UHF	Ultra High Frequency
TDMA	Time Division Multiplexing
OFDM	Orthogonal Frequency Division Multiplexing
WWAN	Wireless Wide Area Network
VoWLAN	Voice Over WLAN
SoS	Security of Service
RTSP	Real Time Signaling Protocol
PIN	Personal Identification Number
POP	Point of Service
PPP	Point to Point Protocol
OSS	Operation Support System
MAC	Medium Access Control
NNTP	Network News Transport Protocol
IANA	Internet Assigned Numbers Authority
FWA	Fixed Wireless Access

DLL	Direct Link Library

1 Introduction

1.1 WLAN

Wireless Local Area Networks (WLAN) is a wireless sharing method that connects devices using high-frequency radio waves. In this advanced technology world and highly competitive market, clients demand a very good wireless network. Wireless network provides a platform where customers can access the network at any time within the coverage area. WLAN provides good scalability to the user and it is possible to add more access points to expand the network and meet user requirement in the near future without any major problems. With the help of gateway, a wider internet connection can be achieved through WLAN. Modern WLAN technologies are mostly based on IEEE 802.11 standards and because of the widespread availability of different terminals WLAN is developing rapidly.

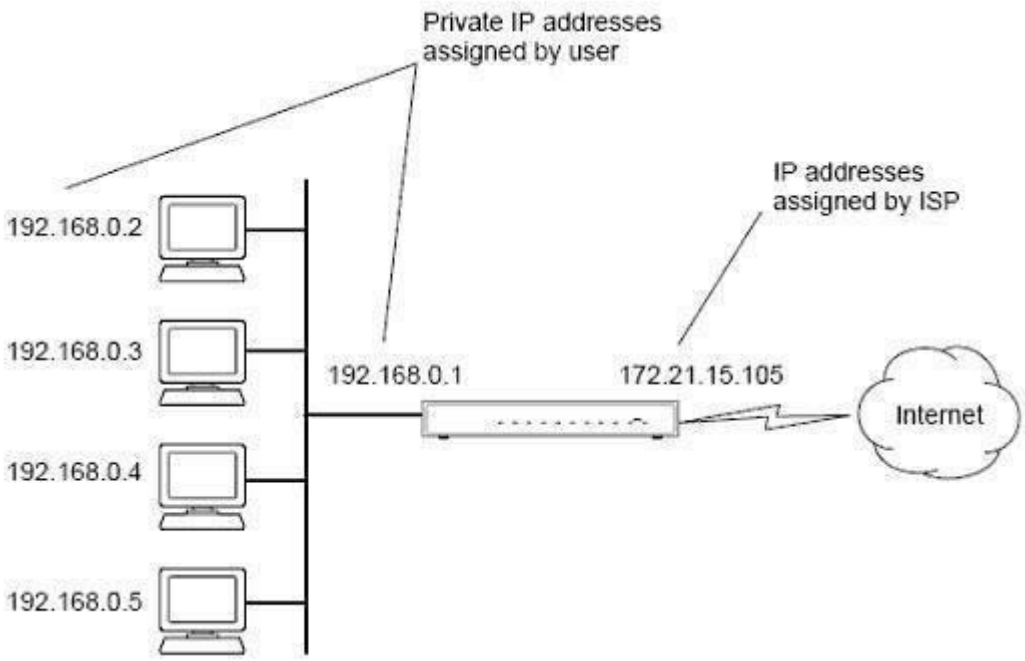


Figure 1. WLAN Architecture

Today, two modes or types of WLANs are generally available. The technology that provides connectivity to the infrastructure network and the technology that provides the connectivity of one device to another. WLAN architecture consists of three main parts i.e. Access points, clients and Bridge. Access points are the special type of routing devices

designed to transmit the data between wired and wireless networking devices. Clients are any sorts of devices like phone, personal computers, laptops which are linked with wireless network. Bridge are the connectors between wired network devices like Ethernet and wireless networks.

2 Methodology

Project success often depends on the proper planning of the project and implementation of proper steps. This five-phased plan helped not only to progress smoothly through the project but also increase knowledge on each and every part of the topic and research.

Stages	Requirements
Phase 1	Planning and pre-survey
Phase 2	Analysis of pre-survey
Phase 3	Actual survey
Phase 4	Analysis and Optimization if necessary
Phase 5	Summary and Conclusion

However, deploying of the wireless access points to optimal locations was not necessary because Ekahau being available, it showed detailed information on signal strength, number of access points present, network health, signal to noise ratio and many more.

3 Theoretical Knowledge

3.1 Benefits of WLANs

3.1.1 Mobility

Mobility refers to the ability to move or moved easily and freely. WLANs gives the ability to roam around the building or institution with proper network connection.

3.1.2 Short term usage

Network system can be connected for a short interval of time with the use of WLAN technology. This feature allows significant operational flexibility and facilitates the formation and support of adhoc working groups. The clients or users can deploy capabilities on an as needed basis with the feature of short term connectivity feature provided by WLANs.

3.1.3 Speed of deployment

WLAN license quick and easy connectivity to the network. With the traditional wired network topology, it is expensive to move new nodes into and out of the system. Whereas WLAN cost comes to almost zero and it is very easy to introduce new nodes and reduces the complexity and its long-term cycle.

3.1.4 Difficult wiring environment

There are always situations or locations where it is not easy or almost impossible to establish a good wired network environment. For instance, historic buildings or museums. Either the wired network environment is very costly or impossible to establish. Similarly, the idea to set up LAN based technology outside environment is virtually impossible. We can consider situations in athletic arenas, open conference halls or any such places where the user wants to have temporary WLAN establishment. WLANs are the best solutions to all these problems.

3.1.5 Scalability

There are basically varieties of ways in which WLAN system can be configured which can meet the requirements of specific applications and installations. Configured WLAN topology can easily be changed as per the requirement and range from independent networks suitable for a tiny group of users to full infrastructure networks of thousands of users that permits roaming over a broad area.

3.2 Issues of WLAN

3.2.1 General issues

One of the most important issues while dealing with WLAN environment is the security. Spectrum is another issue to deal with. The 2.4 GHz band which is the most common band for ISM is overcrowded. Microwave ovens, wireless phones, wireless cameras and many more work in the 2.4 GHz band and they obviously affect the performance of WLANs. Although network standard IEEE 802.11a works on the 5 GHz band it is also an unlicensed band till date. Similarly, actual data rate versus the hype is another issue to deal with. Because of the overheat produced from TCP/IP and MAC layer and collisions the actual data rate achieved is always lower than the expected one. Mobility is also another issue. Mobility between two different networks with service continuity is difficult. Although several vendors like Amazon web server and Microsoft Azure provide network management solutions, network management still remains a big problem for rising new companies and institutions.

3.2.2 Attenuation

Attenuation can be defined as the drop in the signal power when it is transmitted from one place to another. Any phenomenon that can hinder the line of sight signal from transmitter to receiver and vice versa easily causes attenuation. Inside a building infrastructure like furniture, walls, doors cause attenuation whereas outside the building obstacles like hills, houses, forests, vehicles cause attenuation.

3.2.3 Multipath

When the transmitted RF signal is reflected by any path such as buildings or hills than the reflected signal takes multiple paths at the receiver's end. This can cause both constructive as well as destructive interference at the receiving end and occurs in a very short distance. This kind of situation can cause variations ranging from 10 to 30 dB over a short very area and such situation is known as Rayleigh fading. But when the reflected RF signal are completely destructive the received signal power spectrum are deep nulls. However, the received signals can never result into flat signal, it has dips or it fades in the response. Delay spread is the term used when the reflected RF signal has to travel extra path because of the reflections and RF signal arrives later than the expected period of time.

Doppler shift is the situation when the wave source and the receiver are moving relative to each other. When the relative motion is towards each other than the received signal is generally greater compared to the source and when the receiver and source are moving away from one another than the received signal is lower. A significant amount of problem can be caused with Doppler effect when the transmission technique is sensitive to carrier frequency offsets.

3.2.4 UFH Narrowband

RF signals which are sent typically over 12.5 KHZ to 25 KHZ band of spectrum are known as UFH narrowband. Both licensed and unlicensed frequencies are transmitted by UFH narrowband systems. UFH uses the higher power up to 2 watts so that they can achieve longer transmission range.

3.2.5 Infrared

Infrared technology is the invisible light similar to fiber optics which works on the principle line-of-sight links between receiver and transmitter. Physical infrastructure like walls block the invisible infrared light so transmission of signal is limited. Because of this implication infrared light is not used too often WLAN technology today as it was used before.

3.3 IPerf3 Server

IPerf3 is basically a tool which is designed through java programming for the active measurements of the maximum achievable bandwidth on IP networks. IPerf3 server listen to only 5201 default port for connections. IPerf3 needs to listen to TCP/UDP ports for the successful operation with ESS. Requirements for running iPerf3 server are as follows:

- Windows, Mac OSx, Linux which supports Java SE 1.8 or newer versions.
- Connection via Ethernet cable
- TCP port for Incoming connections. (default port 5201)
- UDP traffic on port 5201 allowed
- Network traffic allowed from the wireless survey laptop SSID VLAN all the way to the iPerf server computer.

3.4 Wireless Standards

When working with network planning it is necessary to know about the new WI-FI standards. Better knowledge of the standards helps to make educated network equipment buying decisions and proper planning of the network.

3.4.1 802.11

It was in the year 1997 when IEEE formed the very first wireless standard. 802.11 was named after the group which were responsible for the development of 802.11. However, it supported maximum network bandwidth of only 2 Mbps. Being such a slow network bandwidth, 802.11 standard wireless equipment’s are no longer developed.

3.4.2 802.11b

While the network standard 802.11 was still in progress, IEEE already wanted to improve the network standard and the network standard version 802.11b was in progress in the early 1999. This network standard supports bandwidth up to 11 Mbps. The benefit of using the 802.11b network standard was obviously its cost as it uses the same unregulated radio signaling Frequency which is 2.4 GHz. It also gives little more edge on obstructed signals compared to 802.11.

3.4.3 802.11a

IEEE was already making progress in the development of 802.11a while developing 802.11b. In fact, some developers believe 802.11a was created at the same time as 802.11b because 802.11b gained much more popularity than compared to 802.11a. 802.11a supports maximum bandwidth up to 54 Mbps and the signals are in regulated frequency spectrum around 5 GHz. Because of the regulated frequency 802.11a prevents signal interference from other devices. 802.11a and 802.11b are not compatible with each other as they use different frequencies for network connectivity.

3.4.4 802.11g

This network technology was developed in 2002 and 2003. 802.11g rised on the market to combine the pros of both 802.11a and 802.11b. It uses 2.4 GHz for higher frequency range and can support up to 54 Mbps bandwidth. 802.11g is backward compatible with 802.11b. So, according to IEEE this network technologies access points will work with 802.11b wireless network adapters and vice versa.

3.4.5 802.11n

Also, commonly known as “wireless N” in the technological world was developed by IEEE in the year 2009. This network technology was developed in order to increase the amount of usable bandwidth by proper utilization of multiple antennas and wireless signals (also known as the MIMO technology). This new technology supports network bandwidth up to 300 Mbps. It also has better signal intensity and is backward-compatible with both

802.11b/g gear and vice versa. However, because of the use of multiple signals nearby 802.11b/g based networks might interfere.

3.4.6 802.11ac

This network technology is the latest breakthrough in network standards. 802.11ac operates dual-band wireless technology and is capable of supporting network bandwidth up to 1300 Mbps on 5 GHz and 450 Mbps on 2.4 GHz band. This new network technology is backward compatible with 802.11b/g/n. The figure below shows the comparisons between all the network standards.

IEEE Standard	802.11b	802.11a	802.11g	802.11n	802.11ac
Release Year	1999	1999	2003	2009	2012
Frequency	2.4GHz	5GHz	2.4GHz	2.4or5GHz	5GHz
Data Rate	11Mbps	54Mbps	54Mbps	600Mbps	1Gbps
Modulation	DSSS	OFDM	DSSS,OFDM	OFDM	OFDM

Figure 2. IEEE Network Standards

3.5 Bluetooth

Bluetooth in telecommunications industry is defined as the wireless technology standard for exchanging data over short distances. (Wikipedia). It uses a radio communications

system. This technology was invented in the year 1994 by telecom vendor Ericsson and it was used as a wireless substitute to RS-232 data cables. Till the current date Bluetooth managing company (SIG) claims it has more than 30,000-member companies in the area of telecommunications. Bluetooth technology works at the frequency of 2.4 GHz which data rate can be reached up to 1 Mb/s. The maximum range of Bluetooth connection or operation is only 10 meters. There are number of differences between Bluetooth technology and WLAN. Bluetooth technology can work only in a lower distance range. Nowadays, Bluetooth is mostly used when users need to transfer data between mobile phones. However, Bluetooth technology has less security issues compared to WLAN technologies. IEEE standardized Bluetooth as IEEE 802.15.1. However, Bluetooth technology is not able to maintain the standards set by IEEE.

3.6 HomeRF

HomeRF was a wireless networking technology designed specifically for home network in the year 1998 by Radio Frequency Working Group. This technology is similar to Bluetooth technology. HomeRF operates at the frequency band of 2.4 GHz and provides data rate up to 1 Mb/s. Maximum operation range for this technology is only 50 meters. Proxim Inc, developers of HomeRF claims it have better apparatuses in place to deal with interfering signals like microwave.

4 Measurements and Tools

In this section, all the methods and tools which were used to collect accurate data for the reliable results are discussed.

Several tools and software were used during the period of survey and the project. At the beginning of the project, knowledge and handling of the devices were necessary. Detailed research from the internet and experience of using that software was certainly beneficial. One Laptop that could run the high-level program like channelizer and Ekahau site survey was used along with Ekahau tool packages. Ekahau tool packages included two USB Wi-Fi adapters (NIC-300-USB), one USB hub, one spectrum analyzer and one Motorola smart phone. College map provided by the teacher for the area of survey was

used. Ekahau Iperf3 server was also used to carry out the active throughput testing. Cloud server was used to make a PC iPerf server and carry out the survey. Also, Metropolia Meraki 1 was used to get connection between the iPerf server and the Ekahau NIC-300-USB. Both active and passive surveys were carried out walking through the corridors of the campus area based on the map with the laptop where Ekahau software was installed.

4.1 Passive survey

Passive survey provides more information on radio frequency characteristics such as signal strength, signal to noise ratio, interference level and so on. There are two ways to carry out passive survey, namely stop and go, and continuous walking. Regarding stop and go survey, first the location is chosen. Survey is started by clicking on the starting point of the location and after walking for few meters, it will be stopped. The survey is continued until the whole area is covered. This survey is more time consuming than the other one since data generation process takes more time but the result is more accurate. Moreover, the ease to conduct is also a strength of this approach. The continuous walking method in this survey is somehow similar stop and go but the only difference is that we do not need to stop at certain points/a certain point. The survey conductor continues walking with a steady pace from the starting point to the ending point of the area. The results are less accurate since maintaining a steady pace while carrying out the survey all the time is difficult.

4.2 Active survey

In Active survey, both hardware and software actively link with an access point to gather information such as ping statistics, packet loss, network performance and so on.

4.3 Active Ping Surveys

The end-to-end network performance testing (Ping) is made with the wireless network adapter that is associated with the network in this case Ekahau NIC-300-USB. It is always necessary to check that the network adapter is connected to the Wi-Fi network so it can measure the network performance.

4.4 Active Throughput Surveys

Like the ping surveys, this kind of survey is carried out with the wireless network adapter which is associated with the network. In this survey we need to host an iPerf throughput server (v2 or v3). Ekahau performs active ping survey by defaults. But few configurations are necessary before the survey is carried out. These are the steps to configure the Active Throughput survey.

Step 1

Click on the Adapter and channel config which is available from the Measurement tab from the menu bar of the Ekahau site survey.

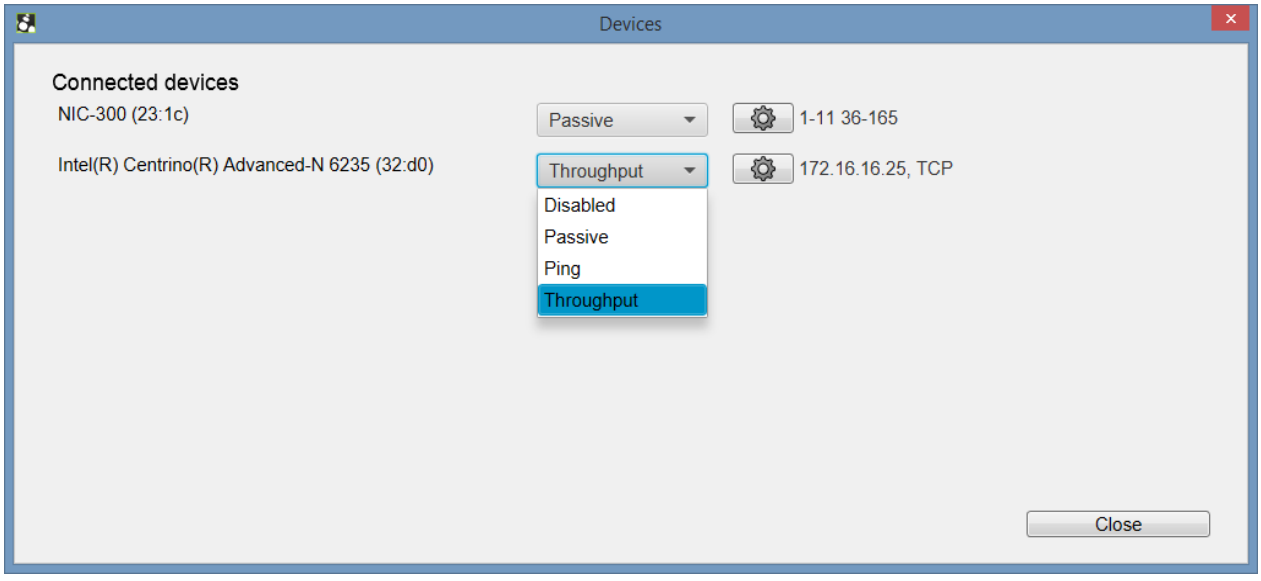


Figure 3. iPerf Surver configuration

Step 2

Throughput test parameters can be set as shown in the picture below.

Mode – iPerf v3

Host – IP address of the throughput server

Protocol – UDP or TCP

Direction – Uplink or downlink (send or receive)

Buffer length – Used as default

Cycle- Time in seconds (Used as default from the Ekahau site survey)

Rate Limit- The bandwidth to send at

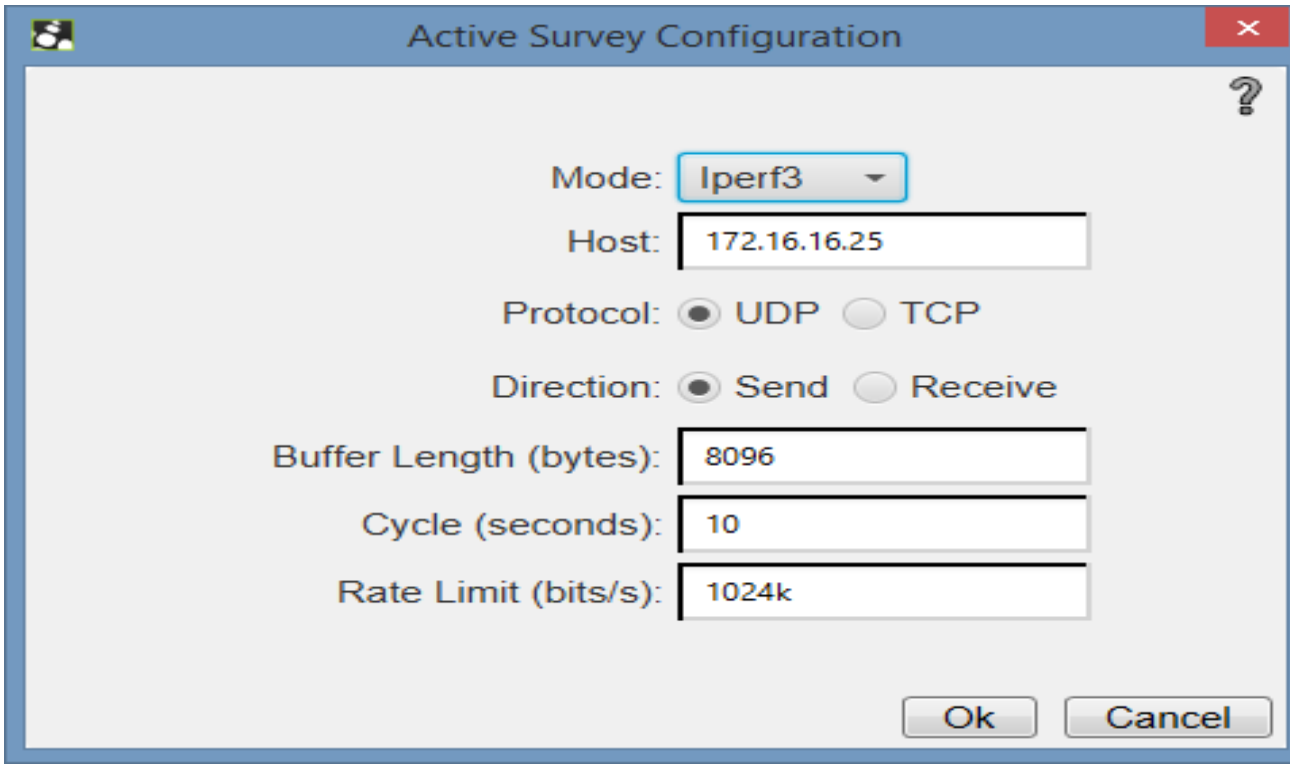


Figure 3. Active Survey Configuration

After the setting is made, make sure to click the play bottom which is located next to the adapter performing the throughput tests. It is necessary to walk through the desired location and in this case survey was made by walking through all the Cisco labs corridors. After completing the survey, we can generate the one click report from the menu bar or just hover the mouse over the access points shown in the map. Which should look like this...

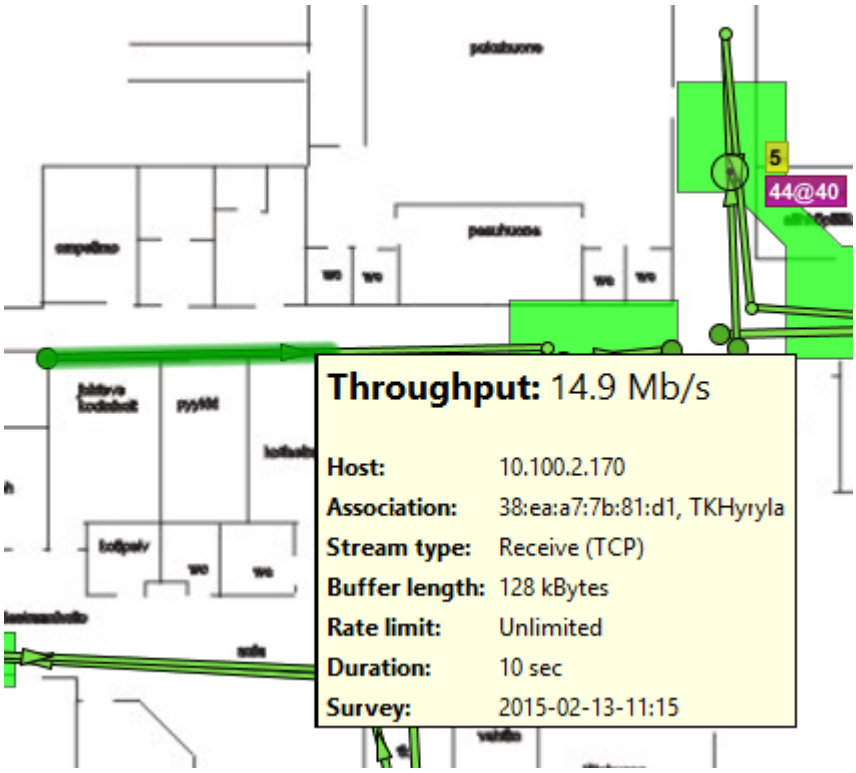


Figure 4. Throughput Measurement

4.5 Spectrum analyzer

Metropolia is a technologically advanced educational institution. Various forms of modern technology and devices are used like cordless phones, wireless detectors, video cameras, ZigBee (IEEE 802.15.4), microwave ovens and so on. Wi-Fi devices serve generally on a license free bands which means frequencies can overlap and interference could occur. Low voice quality, lower network performance than expected, one or more channels unusable for a short period of time or permanently and other suspicious network related issues are the common symptoms of non-Wi-Fi interference signals. So, it is one of the necessity of technologically advanced company or institution like Metropolia to use Spectrum analyzer and troubleshoot the wireless network.

4.5.1 Using the spectrum analyzer

The software called channelizer was used to record and view the data generated from the survey conducted using the spectrum analyzer. Spectrum analyzer surveys are done in a specific location. Walking around the corridor along with a laptop was not necessary. This is mainly because spectrum analyzer takes more time to generate meaningful data. All the surveys were conducted in in the Cisco labs. The results and reports for both 2.4Ghz and 5Ghz bands were generated.

Spectrum analyzer and channelizer software can be summed up in three parts:

1. Navigation pane
2. Overview pane
3. Details pane

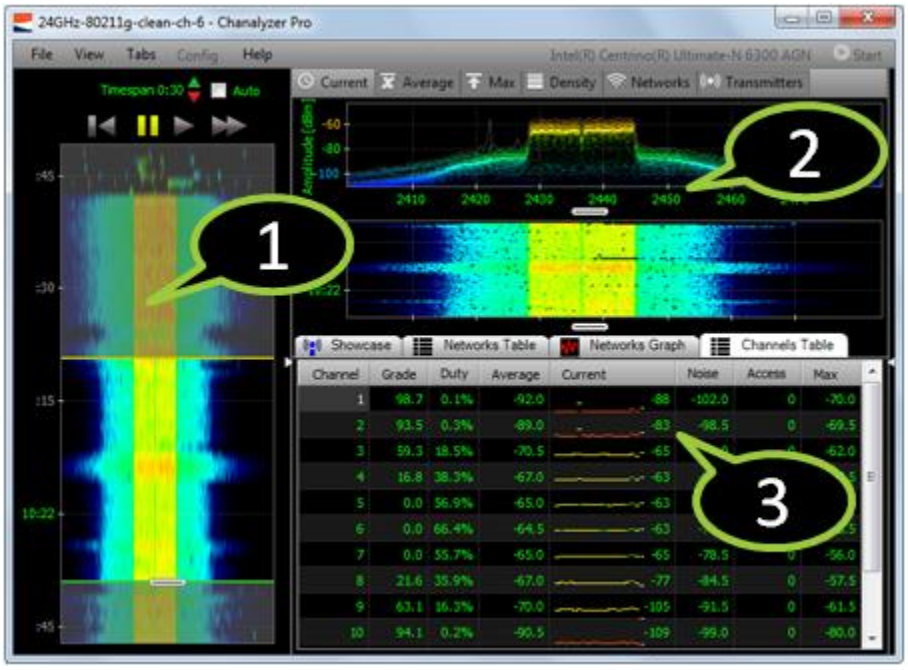


Figure 5. Details of Channelizer

4.5.1.1 Navigation Pane

A session from channelizer for both 2.4Ghz and 5Ghz can be recorded without adding any unnecessary files. Multiple files can be captured at a time. Either frequency or channels can be viewed from the view menu and add both 2.4Ghz and 5Ghz band from wi-spy tab. It is necessary to connect the WIFI from the Ekahau USB-NIC-300.

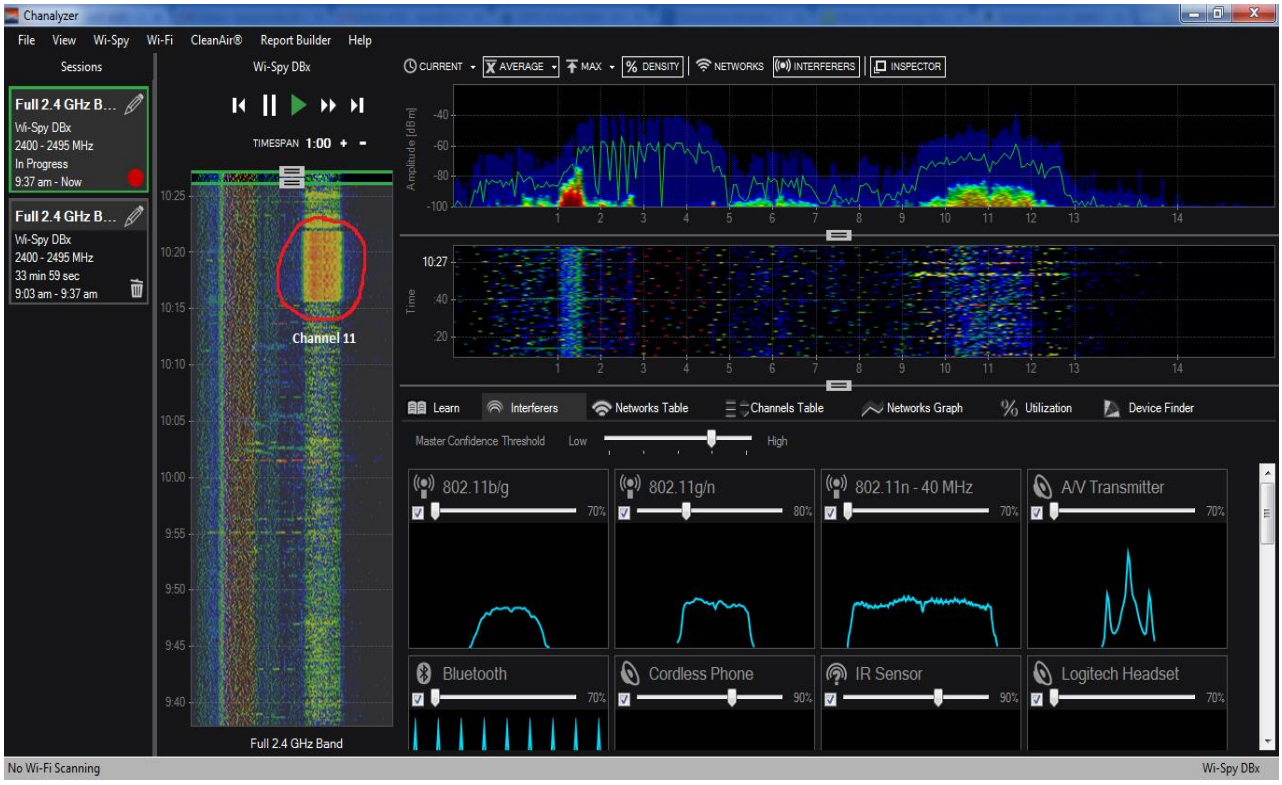


Figure 5. Navigation view from Chanalyzer

There is an option for timespan control which allows to adjust the length of the session to be recorded for and there is also a playback waterfall display with visual indicators which allows the user to go and see in detail the overall session.

4.5.1.2 Overview pane

Overview allows to go back and see in detail what was recorded during the survey. Waterfall view plots the graphs of amplitude over time for each and every frequency in the band. The different colors symbolize the power levels in the spectrum.

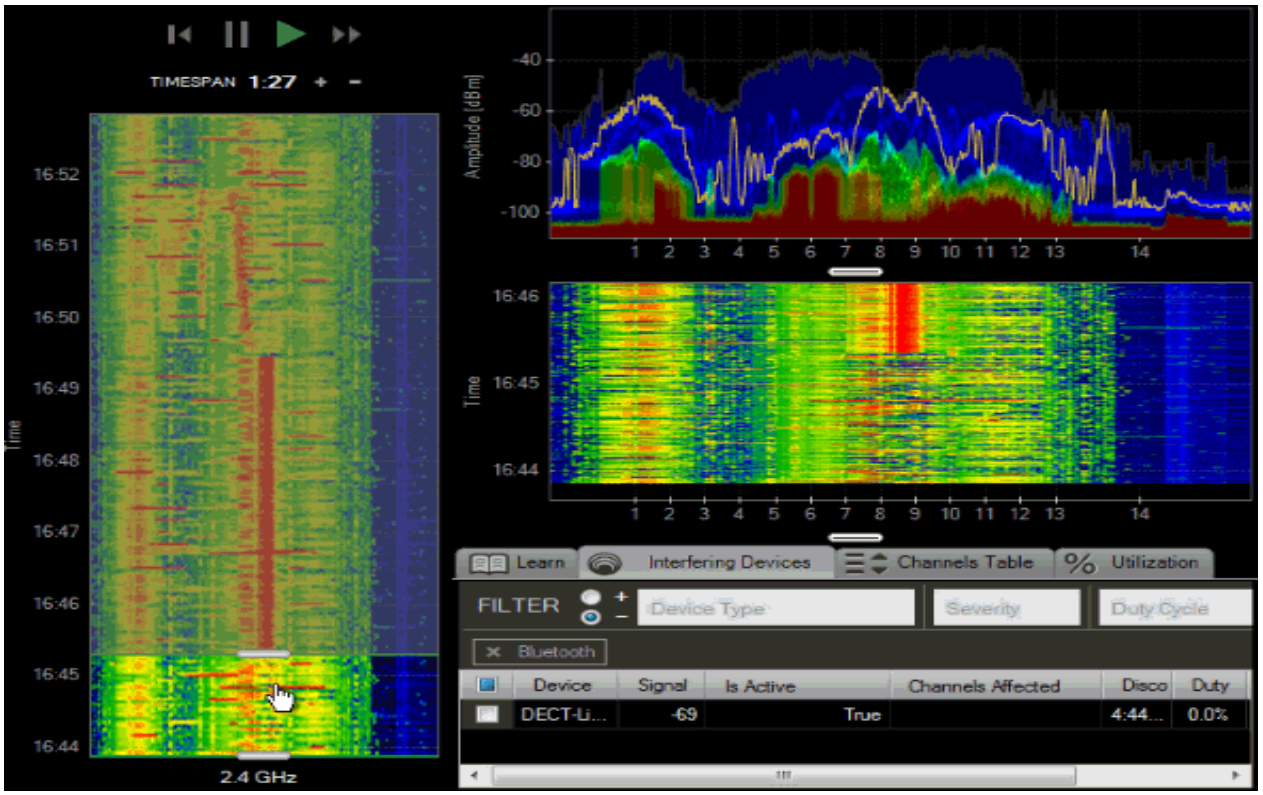


Figure 7. Overview details from Channelizer

Overview also gives the opportunity to view how often an amplitude/frequency point is being used. Density view option is more like the traditional real-time spectrum with a density map generated from most of the used points.

4.5.1.3 Details pane

Details pane shows the network graph, network table and the channels table.

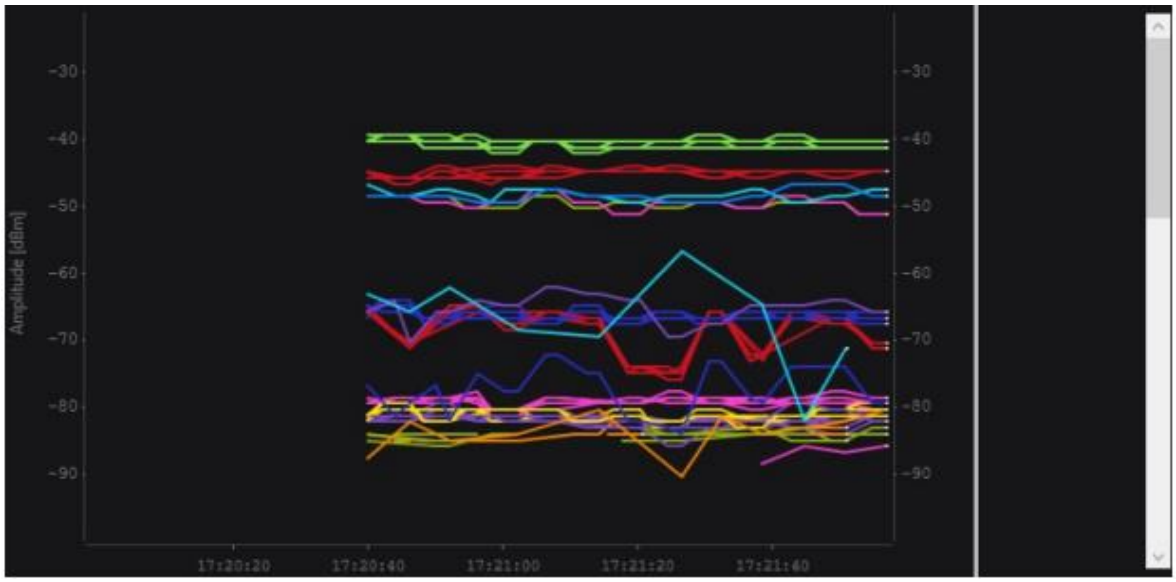


Figure 8. Details Pane View

Network graph shows the WIFI signal strength over time using the data which is collected from Laptop's Wi-Fi card.

Networks Table

ESSID	AP Alias	Channels	Signal Strength (dBm)	BSSID Count	Security	Max Rate (Mbps)	Vendors	802.11
Metropolia Meraki 1		40*	-46,0	1	WPA2-Personal	1300,0		n, ac
metropolia-guest	ety-a0108-2702i, ety-a0115-2702i, ety-a0121a-2802, ety-a1112-2702i, ety-a1117-2802i, ety-a1142-2802i	1, 6, 40*, 44*, 56*, 64*	-36,0	9	Open	600,0	CiscoCisco Systems, Inc	g, n, ac
Metropolia Meraki 2		40*	-47,0	1	WPA2-Personal	1300,0		n, ac
metropolia-secure	ety-a0108-2702i, ety-a0115-2702i, ety-a0121a-2802, ety-a1112-2702i, ety-a1117-2802i, ety-a1142-2802i	1, 6, 40*, 44*, 56*, 64*	-37,0	9	WPA2-Enterprise	600,0	CiscoCisco Systems, Inc	g, n, ac
mediatek	ety-a0108-2702i, ety-a0115-2702i, ety-a0121a-2802, ety-a1112-2702i, ety-a1117-2802i, ety-a1142-2802i	1, 6, 40*, 44*, 56*, 64*	-37,0	9	WPA2-Personal	600,0	CiscoCisco Systems, Inc	g, n, ac
tietotekniikka-lab		1, 6, 40*, 44*, 56*, 64*	-36,0	9	WPA2-Personal	600,0	CiscoCisco Systems, Inc	g, n, ac
eduroam	ety-a0108-2702i, ety-a0115-2702i, ety-a0121a-2802, ety-a1112-2702i, ety-a1117-2802i, ety-a1142-2802i	1, 6, 40*, 44*, 56*, 64*	-37,0	9	WPA2-Enterprise	600,0	CiscoCisco Systems, Inc	g, n, ac
ety-elektroniikka		1, 6, 40*, 44*, 56*, 64*	-37,0	9	WPA2-Personal	600,0	CiscoCisco Systems, Inc	g, n, ac
		1	-47,0	1	WPA2-Personal	288,9	CiscoMerCisco Meraki	b, g, n, ac
		1	-47,0	1	WPA2-Personal	288,9		b, g, n, ac
ProjectOffice		2	-76,0	1	WPA2-Personal	130,0		b, g, n
Neo		4	-66,0	1	WPA2-Personal	72,2	AmigoTecAmigo Technology Co., Ltd.	b, g, n
Duvents		11	-75,0	1	WPA2-Personal	144,4	A-LinkA-Link Ltd	b, g, n
cloud		13	-95,0	1	WPA2-Personal	144,4	A-LinkA-Link Ltd	b, g, n
	Foglab	13	-95,0	1	WPA2-Personal	54,0	CiscoCisco Systems, Inc	b, g

The **Networks Table** displays a snapshot of Wi-Fi access points that were visible from the computer's Wi-Fi card during the selected time period.

Figure 9. Network Table

Network table lists all the wireless access points that are in the range of the computers Wi-Fi card. SSID of all the APs are presented with signal strength.

Channels Table

Channel	Grade	Utilization	Average (dBm)	Current (dBm)	Max (dBm)	Noise Floor (dBm)	Access Points
1	77,9	10,1%	-72,5	-76,0	-58,0	-97,0	26
2	80,4	9,2%	-73,0	-76,0	-58,0	-97,5	1
3	84,2	7,5%	-74,0	-80,5	-59,5	-98,5	0
4	89,1	4,7%	-79,0	-87,5	-63,0	-99,0	1
5	90,3	4,0%	-84,5	-85,0	-65,0	-99,5	0
6	90,8	3,6%	-86,0	-87,5	-67,5	-99,5	6
7	87,8	4,3%	-74,0	-73,0	-67,5	-98,0	0
8	88,6	4,0%	-74,0	-73,0	-68,0	-98,5	0
9	89,3	3,5%	-73,5	-72,5	-64,5	-98,5	0
10	90,5	3,5%	-73,5	-72,5	-64,5	-99,0	0
11	92,7	3,4%	-73,5	-72,5	-64,5	-99,5	1
12	96,3	1,8%	-85,5	-85,0	-65,0	-101,0	0
13	97,7	1,2%	-87,0	-100,5	-68,0	-101,0	2
14	99,9	0,0%	-96,0	-100,5	-77,0	-102,0	0

Figure 10. Channel Table

Channels Table ranks all the Wi-Fi channel according to the characteristics shown by RF activity within its given frequencies and time range selected in the navigation pane. The primary use of the Channel table is to use in the arrangement of new wireless devices. This table takes into account all the RF noise occurring within the Wi-Fi channels. The Channel Grade is a weight for each amplitude or frequency point based on how close it is to the center of the channel and its amplitude. Duty cycle measures how much RF activity is occurring in the channel within the channels frequencies and the specified time range in the navigation pane and is weighted so that signals near the center of the channel have a greater effect on the duty cycle score. So, the duty cycle helps to determine whether the channel is adaptable or not. The maximum value is the highest amplitude point captured within the Wi-Fi channel frequency range. The average is a measurement of the average power within the channel frequency range.

4.6 Finding the interference signals

The aim of using the Ekahau spectrum analyzer is to find out the interferences in the existing Wi-Fi frequencies. The channelizer will automatically try to identify the interference sources. Interferers can be recognized using the patterns they make in the density

views. There is library of the interferer identifier patterns which are placed in the Interferers tab.

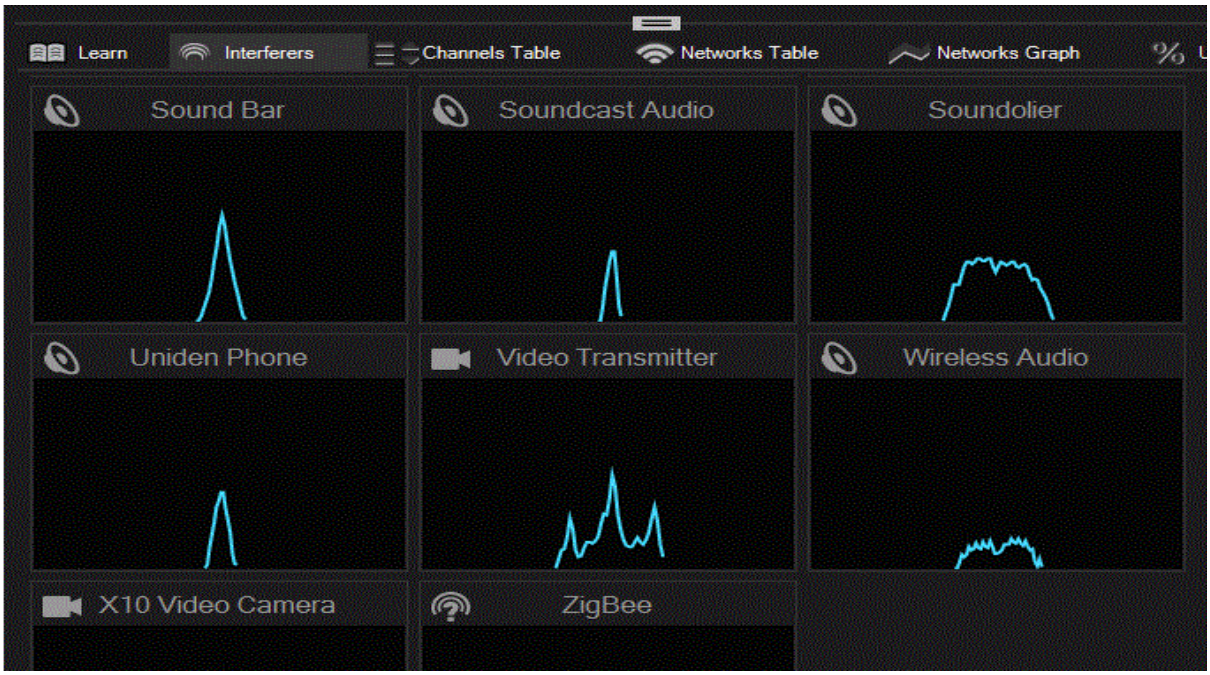
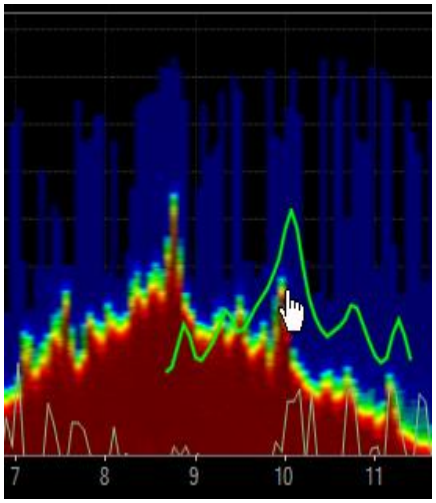


Figure 11. Interference Patterns



Interferers pattern can be matched with the above patterns shown when the mouse is hovered over the density view graph.

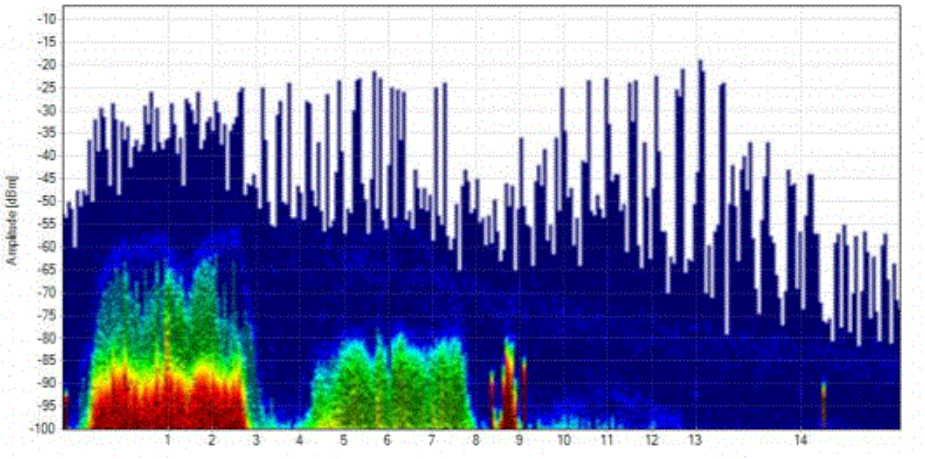


Figure 12. Density View Graph

Almost every room examined showed a similar picture. It shows channel 1 is over-crowded while channel 11 is equal to wasted. There is an interference signal between channel 8 and channel 9. However, Metropolia UAS network system uses channel 1,6 and 11 on 2.4GHz band because of the non-overlapping signal. Thus, there is no impact on the network performance whatsoever. After little bit of research, the interferer was from a wireless sensor located in every room where the survey was carried out.

5 Results and Analysis

To ensure the accuracy of the project several site surveys were conducted around the campus corridors. Every survey result was recorded in a PDF format and stored for future use. All the files and figures generated from the survey can be used for the better under-standing and analysis of the network status of the campus.

5.1 Survey routes and Access Points

Figure 13. Survey map, Routes and Access Points

5.2 Signal strength

Signal Strength also known as the coverage area is one of the most important obligation for a wireless network. Low signal strength leads to unreliable connections, low data throughput and vice versa. It is measured in dBm or mW. dBm is decibels relative to 1 milliwatt whereas mW is one thousandth of a watt.

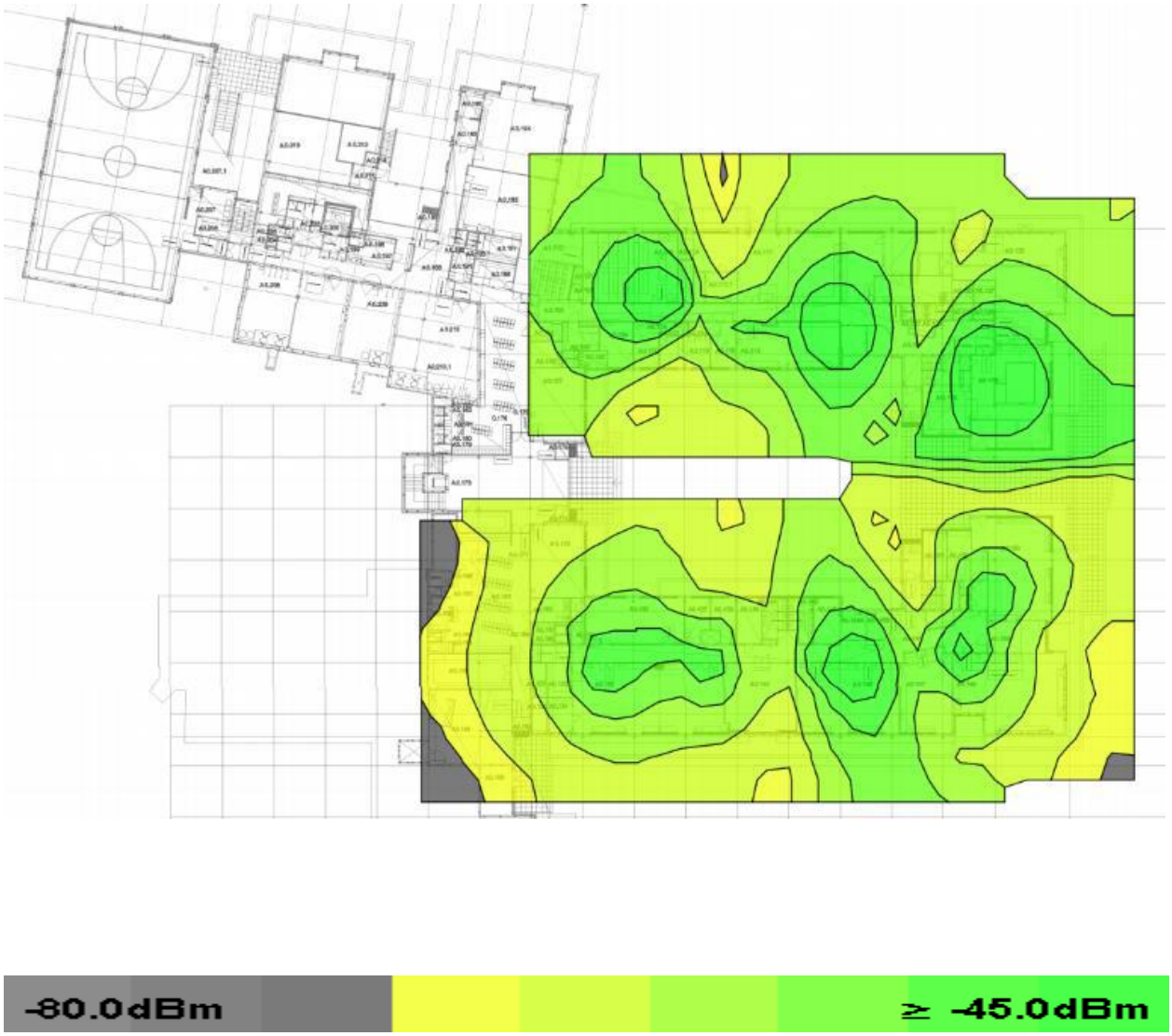


Figure 14. Signal strength on 2.4 GHz

Figure 15. Signal strength on 5 GHz

In our case it can be clearly seen that both 2.4 GHz and 5 GHz are well covered within the surveyed area. There is at least one AP placed in every classroom so the signal strength is very good in the class room area.

5.3 Signal to Noise Ratio (SNR)

Signal to noise ratio shows how much is the signal strength stronger than the noise or interference. Or according to Wikipedia it is defined as the transmitter power output as received by a reference antenna at a distance from the transmitting antenna.

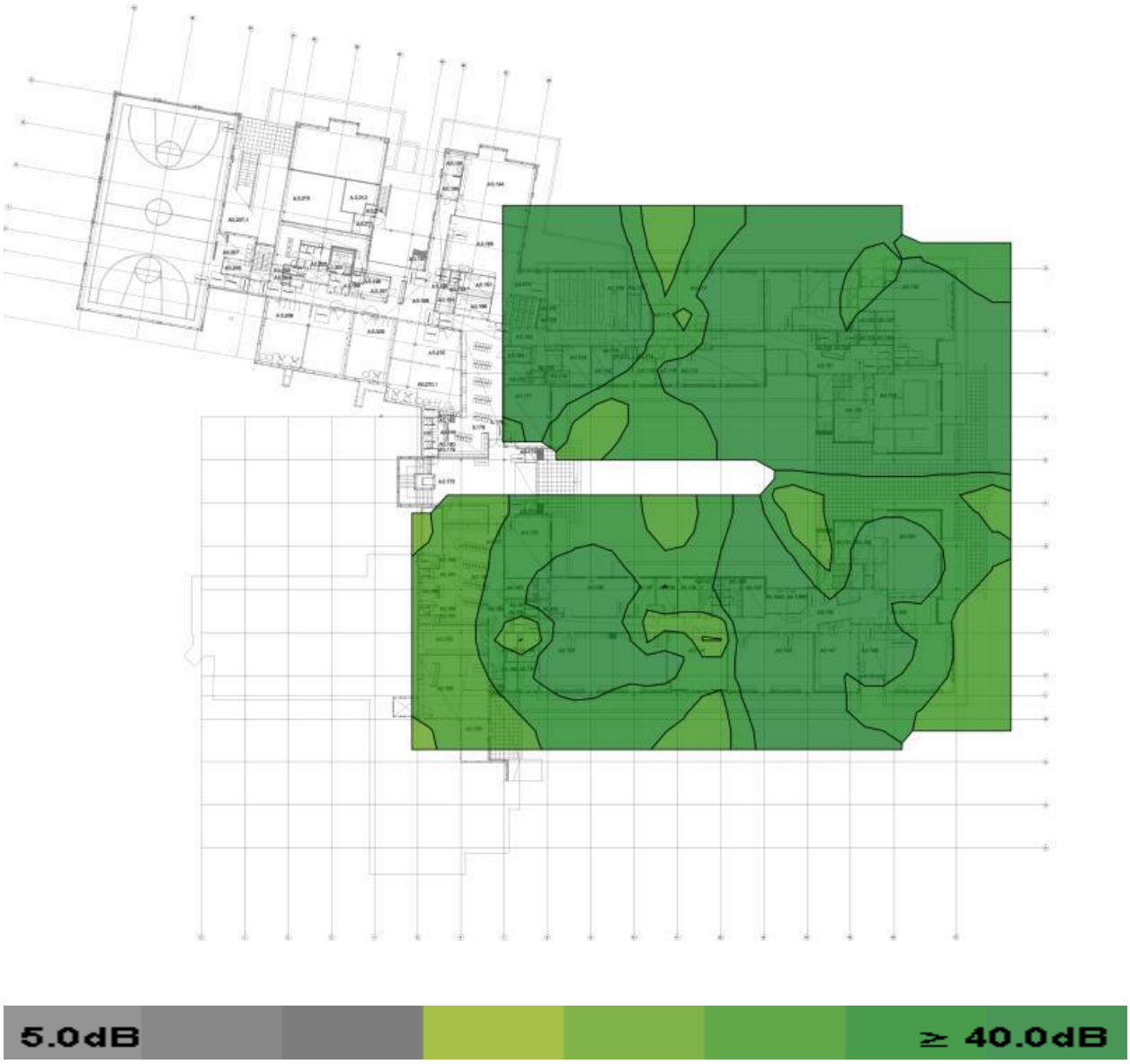


Figure 16. SNR on 2.4Ghz band

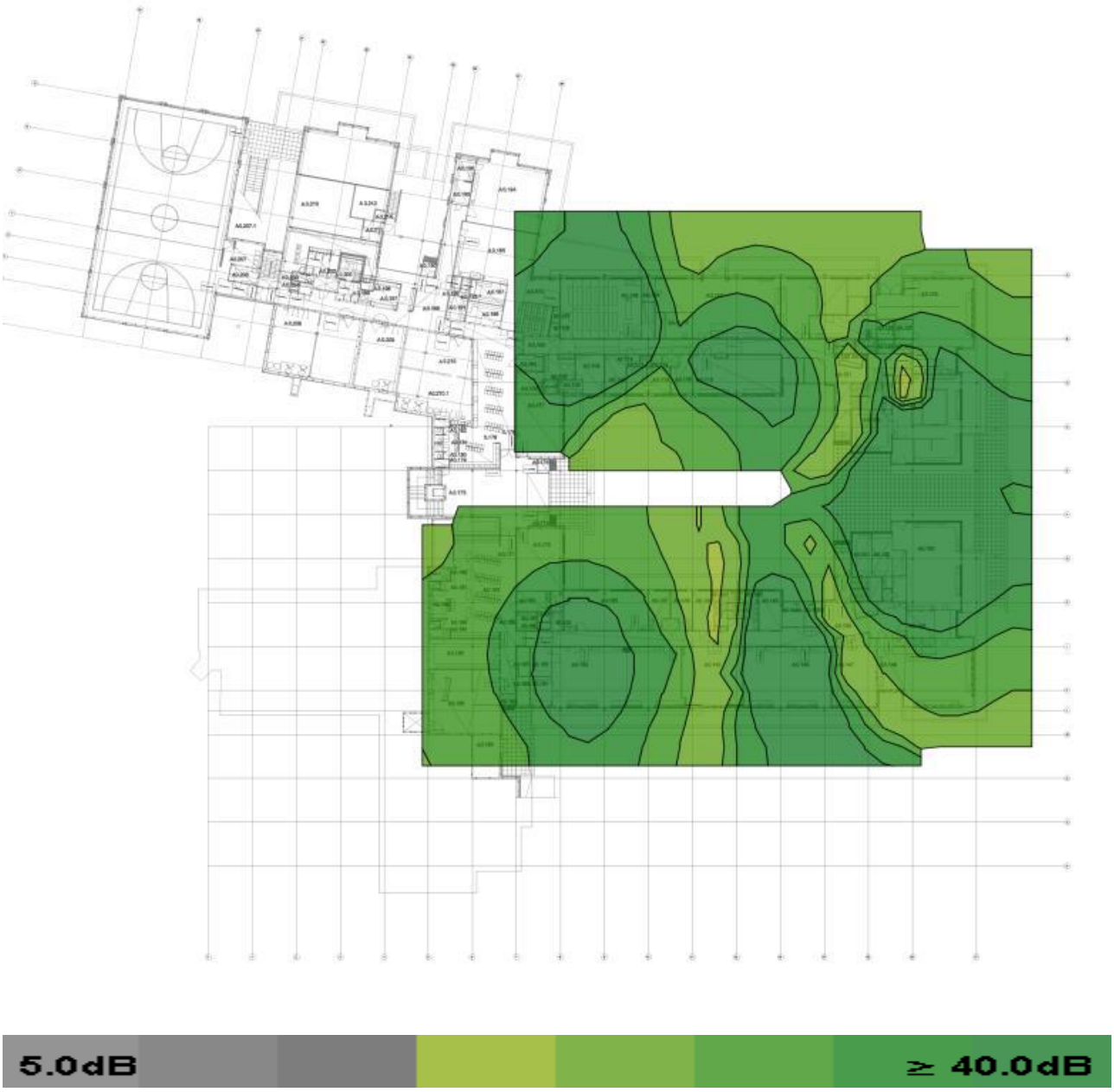


Figure 17. SNR on 5Ghz band

The signal-to-noise ratio is the value representing how much the signal strength is stronger than the noise. That simply means this value must be high enough for a good data transfer. The figures below illustrates the information on the SNR on both 2.4Ghz and 5Ghz bands. This value is quite high for the whole surveyed area, at about 40dB. The data indicates that the signal strength value is roughly

10000 times more than the noise strength value, which is high enough for a good data transmission between users' devices and APs.

5.4 Channel Overlap

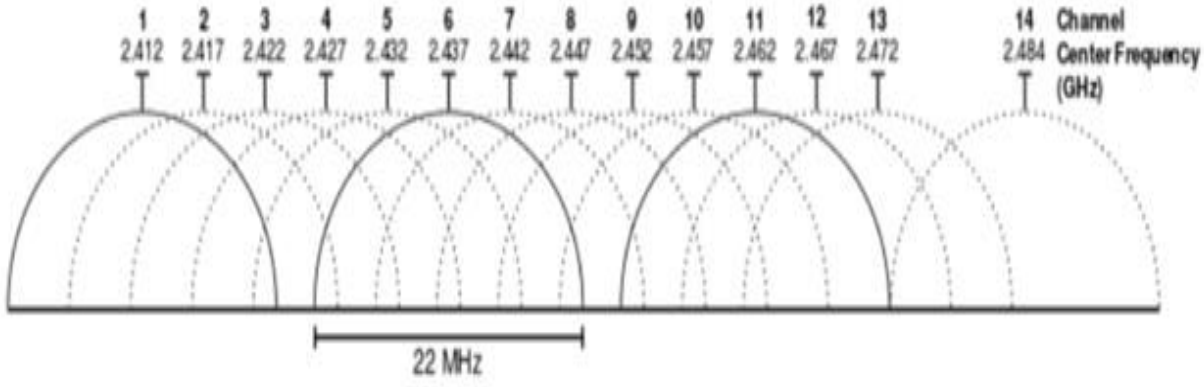


Figure 18. Non-Overlapping Channels

802.11bgn radios utilize the 2.400-2.500 GHz spectrum. The 2.4Ghz frequency band is divided into maximum of 14 channels which are spaced to 5MHz apart. Each channel is 22 MHz wide. There are only three non-overlapping channels 1,6,11 for 2.4 GHz frequency band.

- Channel 1 Frequency Range: 2.401 to 2.423 GHz
- Channel 6 Frequency Range: 2.426 to 2.448 GHz
- Channel 11 Frequency Range: 2.451 to 2.473 GHz

802.11a/n/c radios utilize the 5 GHz UNII bands(1,2,2E,3) which are 20,40,80,160 MHz wide bandwidths. In 5 GHz frequency band there are total of 24 non-overlapping 20 MHz channels.

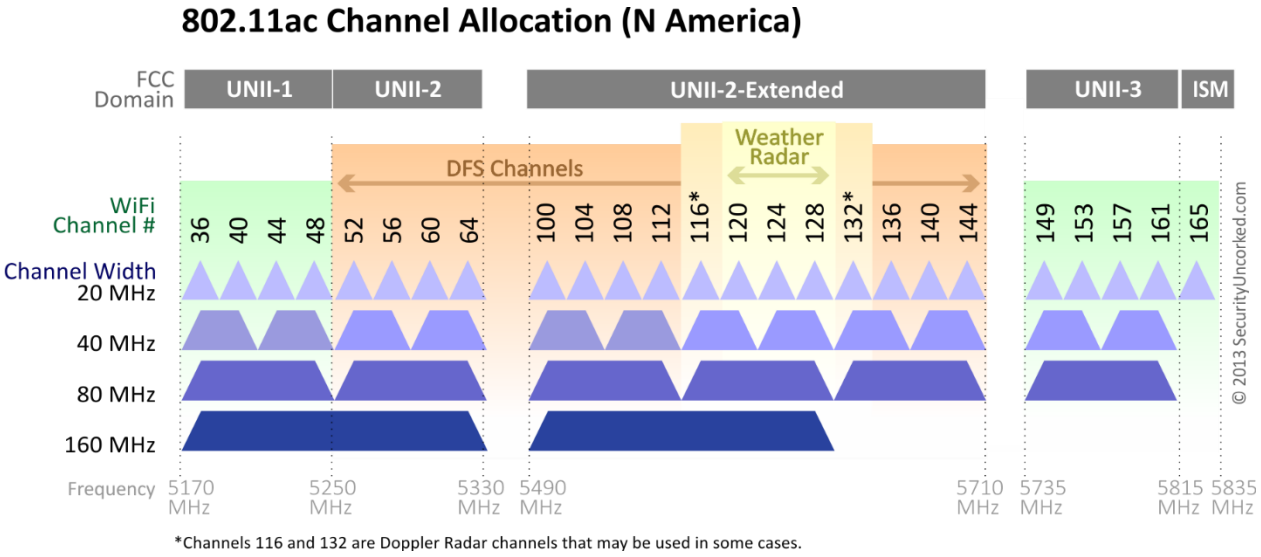


Figure 19. Channel Allocation

Channel overlap indicates the number of access points audible at each location in a single channel.

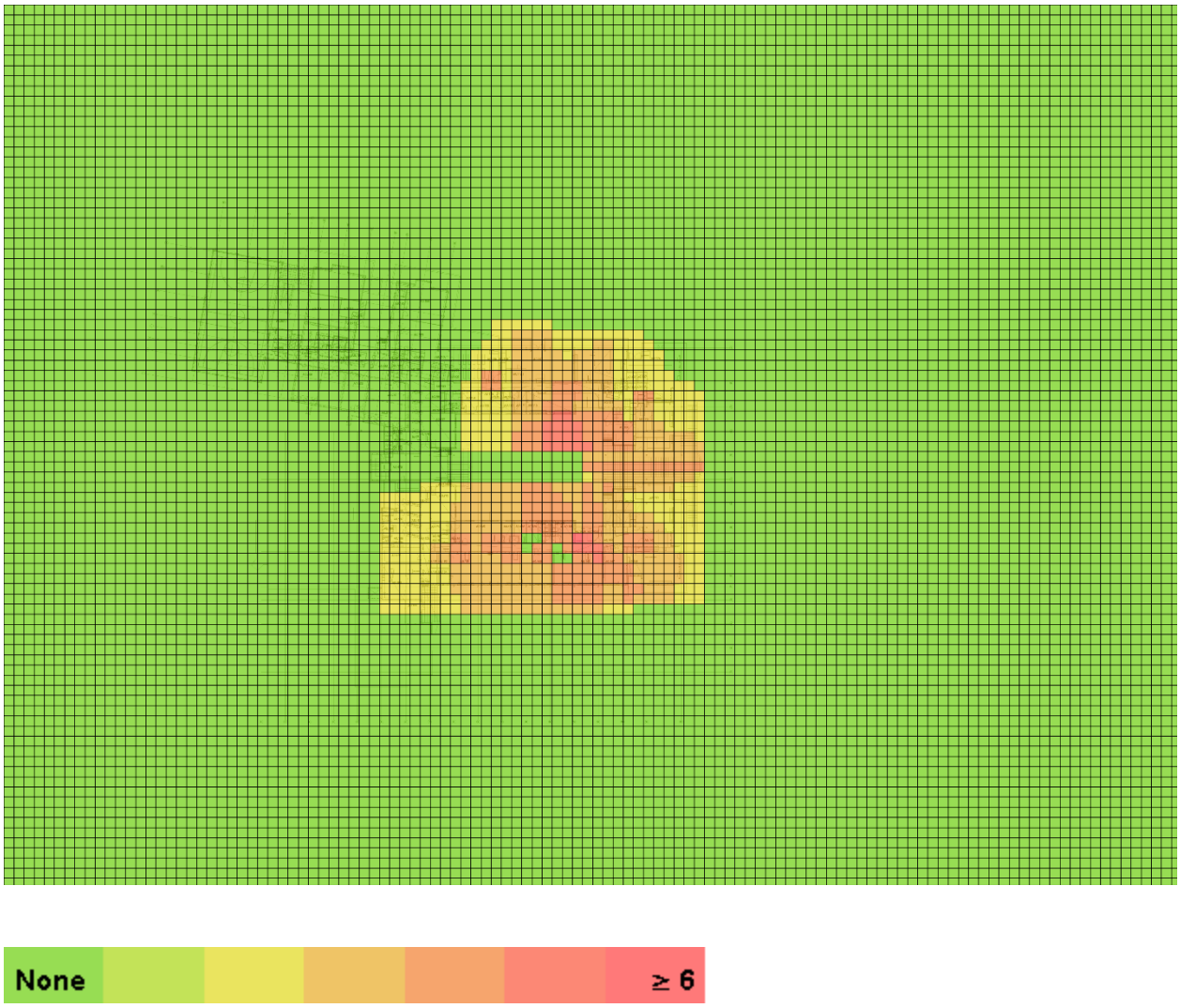


Figure 20. Channel Overlap on 2.4Ghz band

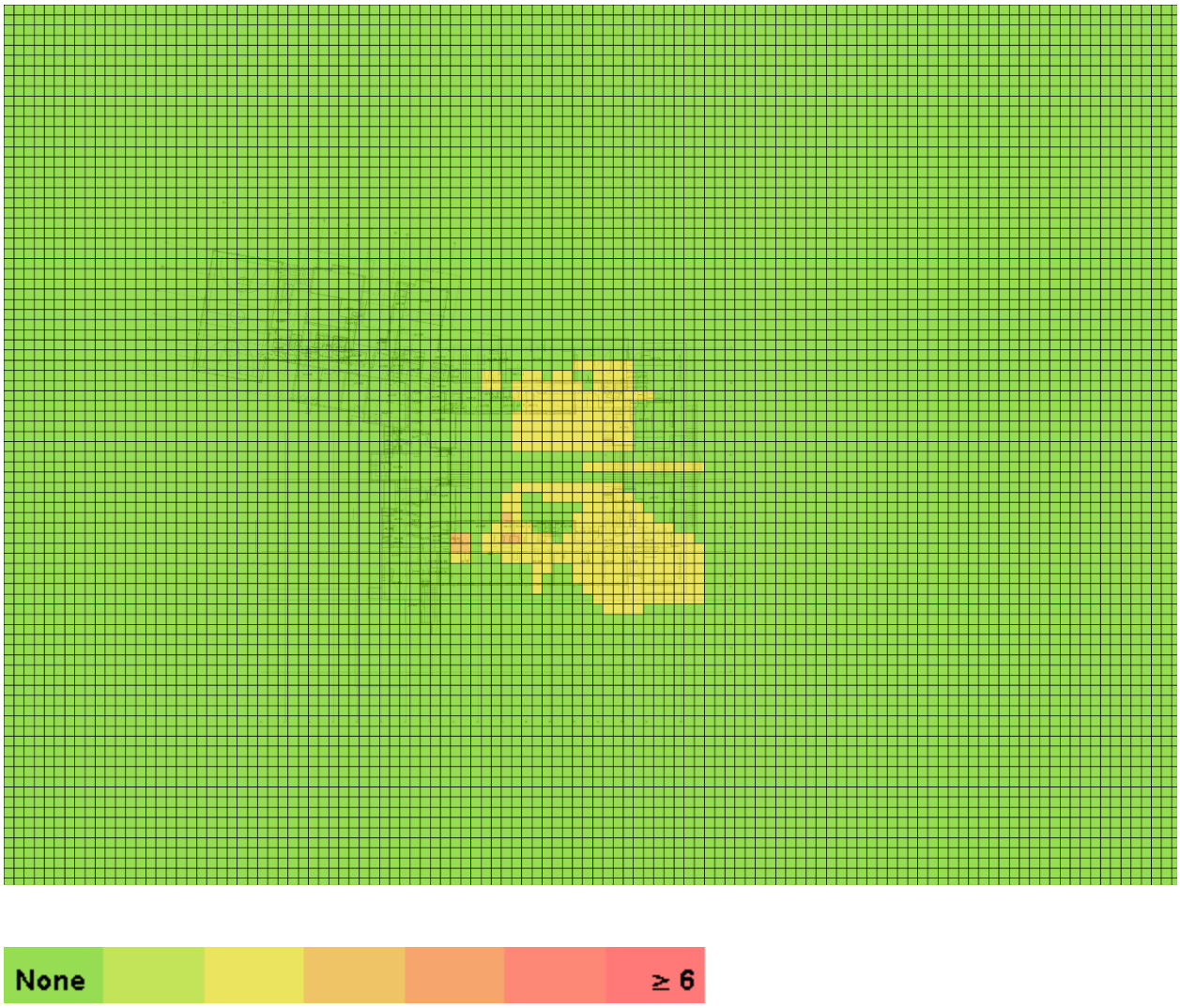


Figure 21. Channel Overlap on 5Ghz band

5.5 Interference/Noise

The following graph shows the interference or noise level in the established network of the survey area which is measured by the network adapter. The measured noise is the

sum of thermal noise for given bandwidth and the noise received from the environment. For 20 MHz channel, the best possible noise floor is -101 dBm, however, due to additional noise for 2.4 GHz it is often slightly higher. (Ekahau site survey)

Figure 22. Interference/noise on 2.4Gh

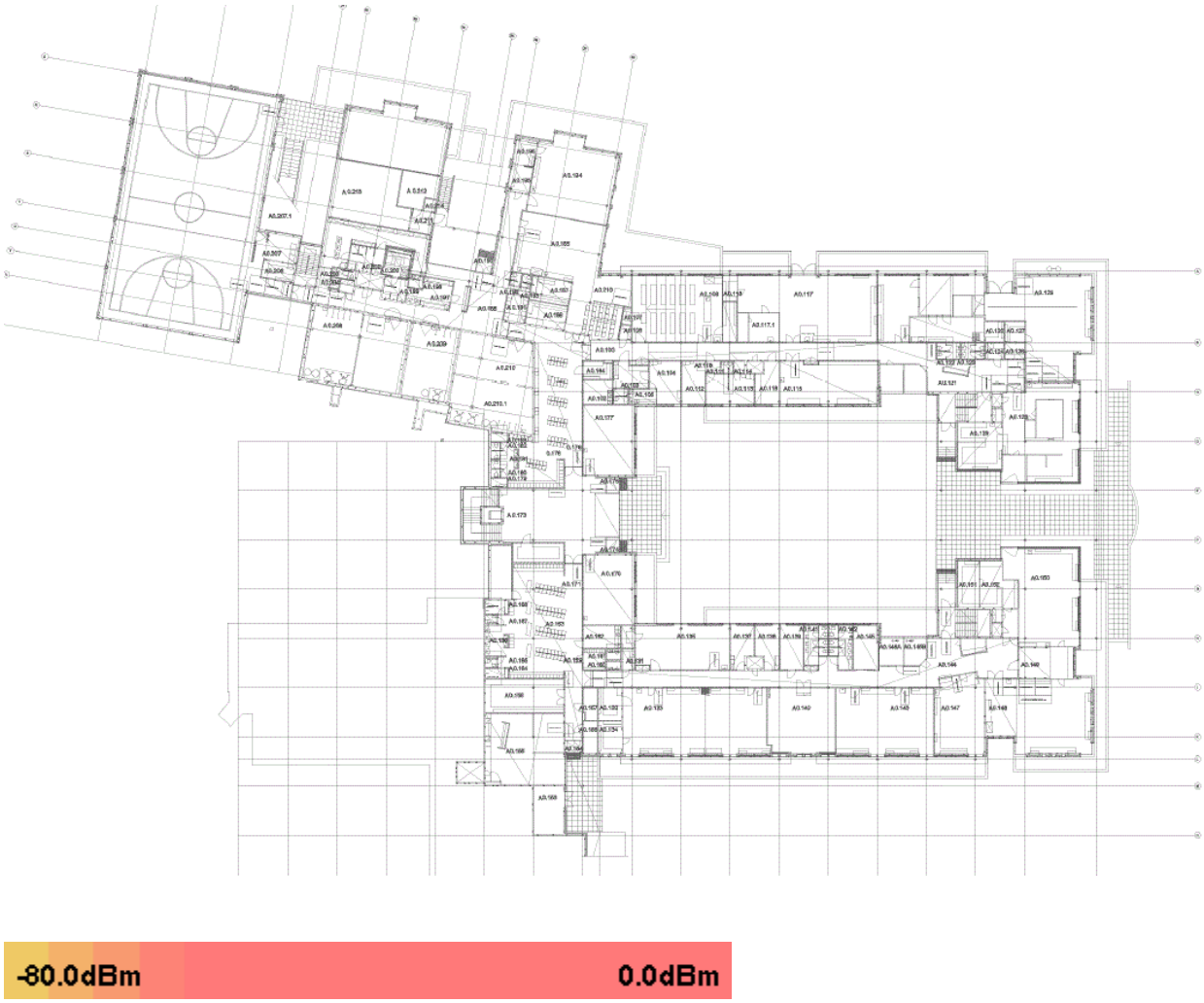


Figure 23. Interference/noise on 5GHz

5.6 Data Rate

Data rate is the highest possible speed at which the wireless devices will be transmitting data. Modulation techniques, coding rate, guard interval size, channel bandwidth and many more play special role in determining the data rates. 802.11n supports data rates up to 600 Mbps with 4 spatial streams, 64-QAM, 5/6 coding rate, 40 MHz channel bandwidth and a 400-ns short guard interval.

MCS index	Spatial streams	Modulation type	Coding rate	Data rate (Mbit/s)			
				20 MHz channel		40 MHz channel	
				800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	1	BPSK	1/2	6.50	7.20	13.50	15.00
1	1	QPSK	1/2	13.00	14.40	27.00	30.00
2	1	QPSK	3/4	19.50	21.70	40.50	45.00
3	1	16-QAM	1/2	26.00	28.90	54.00	60.00
4	1	16-QAM	3/4	39.00	43.30	81.00	90.00
5	1	64-QAM	2/3	52.00	57.80	108.00	120.00
6	1	64-QAM	3/4	58.50	65.00	121.50	135.00
7	1	64-QAM	5/6	65.00	72.20	135.00	150.00
8	2	BPSK	1/2	13.00	14.40	27.00	30.00
9	2	QPSK	1/2	26.00	28.90	54.00	60.00
10	2	QPSK	3/4	39.00	43.30	81.00	90.00
11	2	16-QAM	1/2	52.00	57.80	108.00	120.00
12	2	16-QAM	3/4	78.00	86.70	162.00	180.00
13	2	64-QAM	2/3	104.00	115.60	216.00	240.00
14	2	64-QAM	3/4	117.00	130.00	243.00	270.00
15	2	64-QAM	5/6	130.00	144.40	270.00	300.00
16	3	BPSK	1/2	19.50	21.70	40.50	45.00
17	3	QPSK	1/2	39.00	43.30	81.00	90.00
18	3	QPSK	3/4	58.50	65.00	121.50	135.00
19	3	16-QAM	1/2	78.00	86.70	162.00	180.00
20	3	16-QAM	3/4	117.00	130.00	243.00	270.00
21	3	64-QAM	2/3	156.00	173.30	324.00	360.00
22	3	64-QAM	3/4	175.50	195.00	364.50	405.00
23	3	64-QAM	5/6	195.00	216.70	405.00	450.00
24	4	BPSK	1/2	26.00	28.80	54.00	60.00
25	4	QPSK	1/2	52.00	57.60	108.00	120.00
26	4	QPSK	3/4	78.00	86.80	162.00	180.00
27	4	16-QAM	1/2	104.00	115.60	216.00	240.00
28	4	16-QAM	3/4	156.00	173.20	324.00	360.00
29	4	64-QAM	2/3	208.00	231.20	432.00	480.00
30	4	64-QAM	3/4	234.00	260.00	486.00	540.00
31	4	64-QAM	5/6	260.00	288.80	540.00	600.00

Figure 24. Detail View of Data Rate Table

The above table shows all the possible data rates for 802.11n.

Similarly, 802.11 ac is hypothetically capable to support data rates up to 6993 Mbps with 8 spatial streams, 256- QAM, 5/6 coding rate, 160 MHz channel bandwidth and a 400-

ns short Guard Interval. However, in real world it is impossible to achieve such a high data rate because of the presence of environmental radio properties. A more reasonable data rate achievable is around 346.7 Mbps at 20 MHz.

SELECTED 802.11AC RATES IN MBPS (SHORT GUARD INTERVAL, 1, 2, 3, 4, 8 SS)

MCS	Modulation & Rate	20 MHz 1x SS	20 MHz 2x SS	20 MHz 4x SS	20 MHz 8x SS	40 MHz 1x SS	40 MHz 2x SS	40 MHz 4x SS	40 MHz 8x SS	80 MHz 1x SS	80 MHz 2x SS	80 MHz 4x SS	80 MHz 8x SS	160 MHz 1x SS	160 MHz 2x SS	160 MHz 4x SS	160 MHz 8x SS
0	BPSK 1/2	7.2	14.4	28.9	57.8	15.0	30.0	60.0	120.0	32.5	65.0	130.0	260.0	65.0	130.0	260.0	520.0
1	QPSK 1/2	14.4	28.9	57.8	115.6	30.0	60.0	120.0	240.0	65.0	130.0	260.0	520.0	130.0	260.0	520.0	1040.0
2	QPSK 3/4	21.7	43.3	86.7	173.3	45.0	90.0	180.0	360.0	97.5	195.0	390.0	780.0	195.0	390.0	780.0	1560.0
3	16-QAM 1/2	28.9	57.8	115.6	231.1	60.0	120.0	240.0	480.0	130.0	260.0	520.0	1040.0	260.0	520.0	1040.0	2080.0
4	16-QAM 3/4	43.3	86.7	173.3	346.7	90.0	180.0	360.0	720.0	195.0	390.0	780.0	1560.0	390.0	780.0	1560.0	3120.0
5	64-QAM 2/3	57.8	115.6	231.1	462.2	120.0	240.0	480.0	960.0	260.0	520.0	1040.0	2080.0	520.0	1040.0	2080.0	4160.0
6	64-QAM 3/4	65.0	130.0	260.0	520.0	135.0	270.0	540.0	1080.0	292.5	585.0	1170.0	2340.0	585.0	1170.0	2340.0	4680.0
7	64-QAM 5/6	72.2	144.4	288.9	577.8	150.0	300.0	600.0	1200.0	325.0	650.0	1300.0	2600.0	650.0	1300.0	2600.0	5200.0
8	256 QAM 3/4	86.7	173.3	346.7	693.3	180.0	360.0	720.0	1440.0	390.0	780.0	1560.0	3120.0	780.0	1560.0	3120.0	6240.0
9	256-QAM 5/6	-	-	-	-	200.0	400.0	800.0	1600.0	433.3	866.7	1733.3	3466.7	866.7	1733.3	3466.7	6933.3

Figure 25. Data Rates Supported by 802.11ac

The above table shows various supported data rates for 802.11ac.

How does ESS calculate the data rate?

By default, my access points for calculated data rate are displayed by ESS. Data rate is based on the minimum signal strength and SNR and SNR is affected by signal strength and noise level. Therefore, Network load affects the data rate. The higher the network load, the more is the interference level which leads to lower SNR and low data rates. Also, the data rates calculated by ESS may differ according to the different adapters used since the adapters have different receiver capabilities. For example, 802.11b adapter can only communicate at a maximum of 11 Mbps.

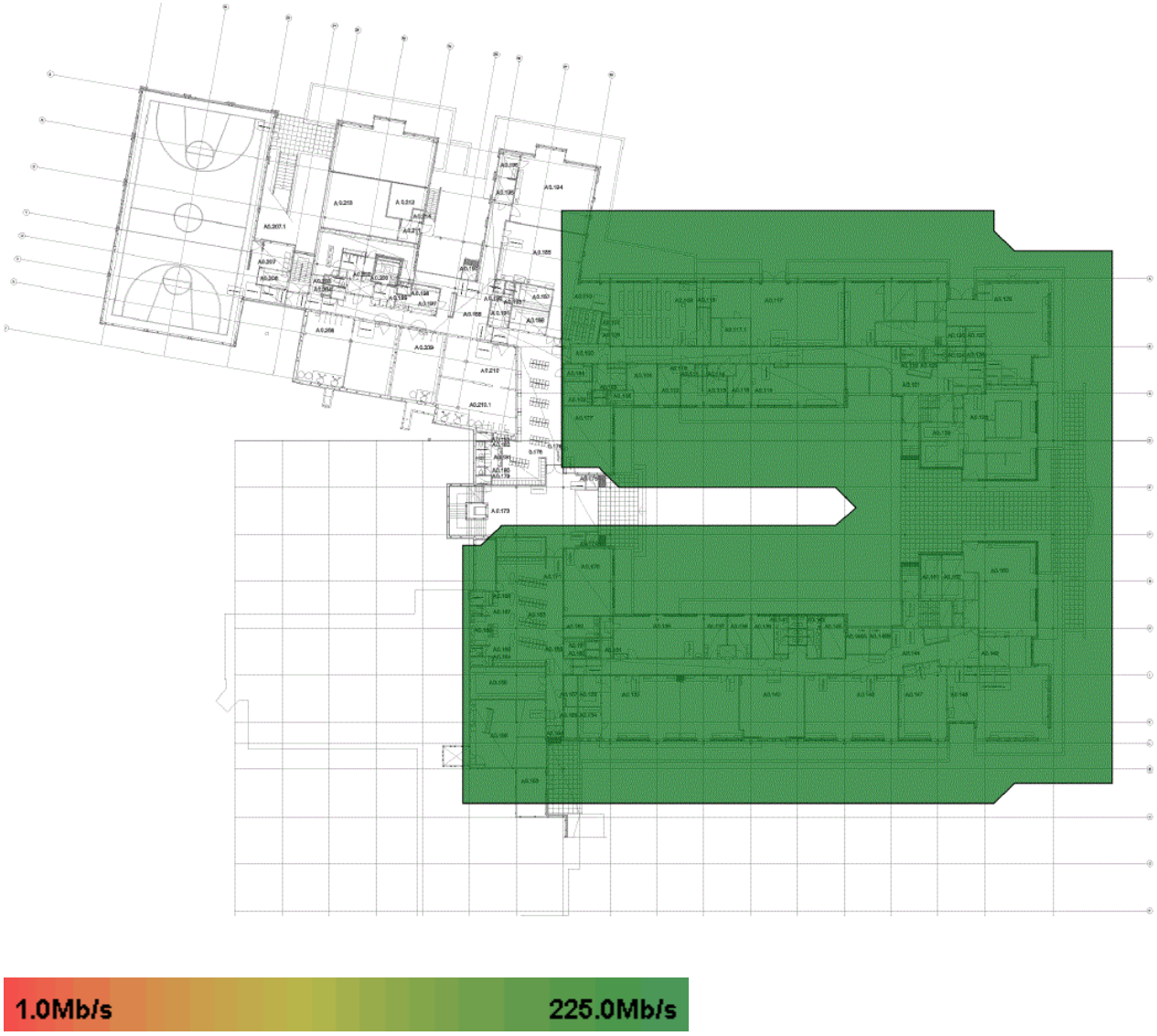


Figure 26. Data rate on 2.4GHz

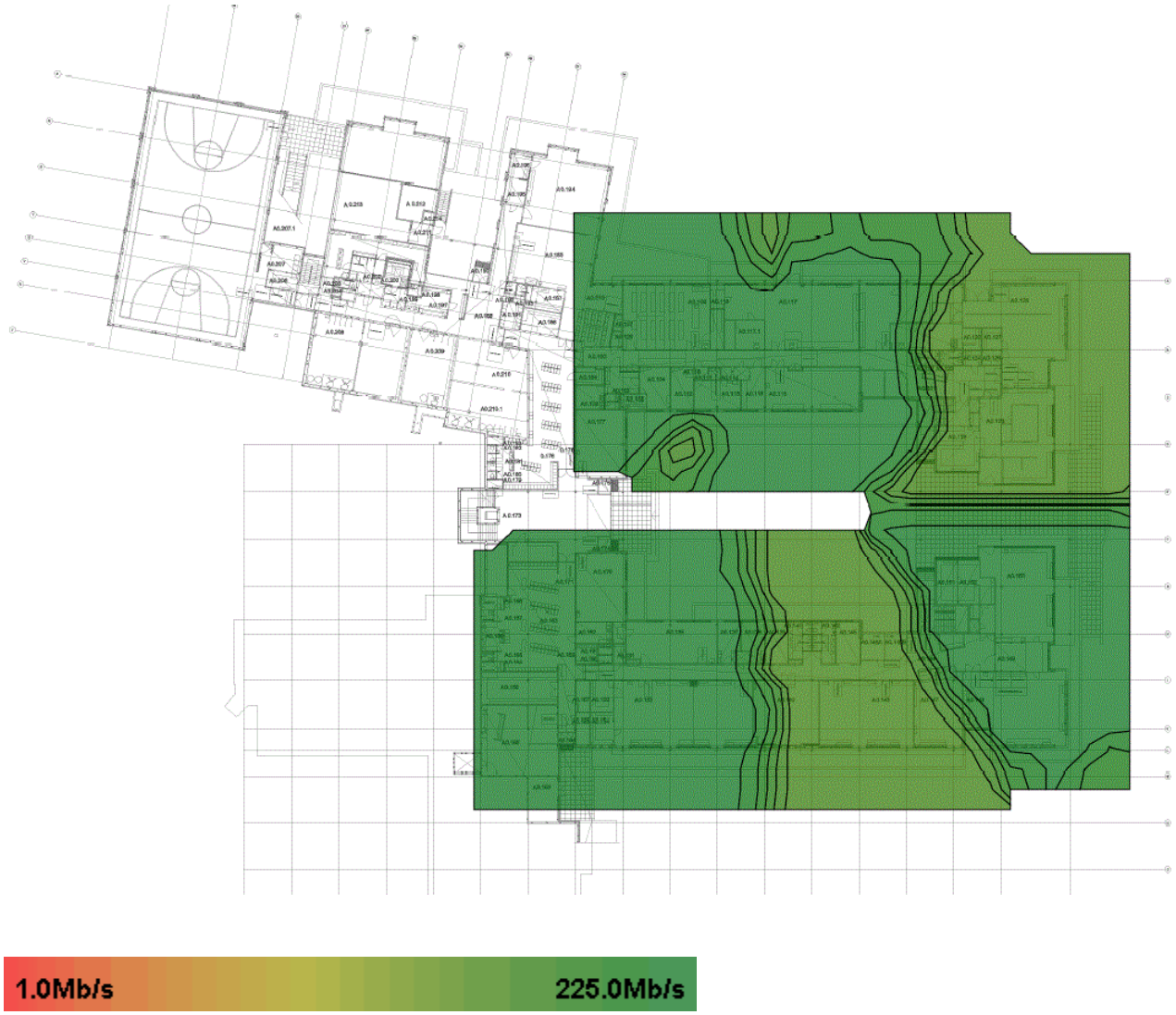


Figure 27. Data rate on 5GHz

5.7 Packet Loss

Packet loss shows how many replies did not arrive to a sent packet.

Figure 28. Packet loss

Requirement criteria for Network Requirements

	Signal Strength Min	-67.0 dBm	
	Signal-to-noise Ratio Min	20.0 dB	
	Data rate Min	20 Mbps	
	Number of Access Points Min	2	at min. -75.0 dBm
	Channel Overlap Max	2	at min. -85.0 dBm
	Round Trip Time (RTT) Max	200ms	
	Packet Loss Max	2.0 %	

Figure 29. Network Requirement Criteria

5.8 Network Issues

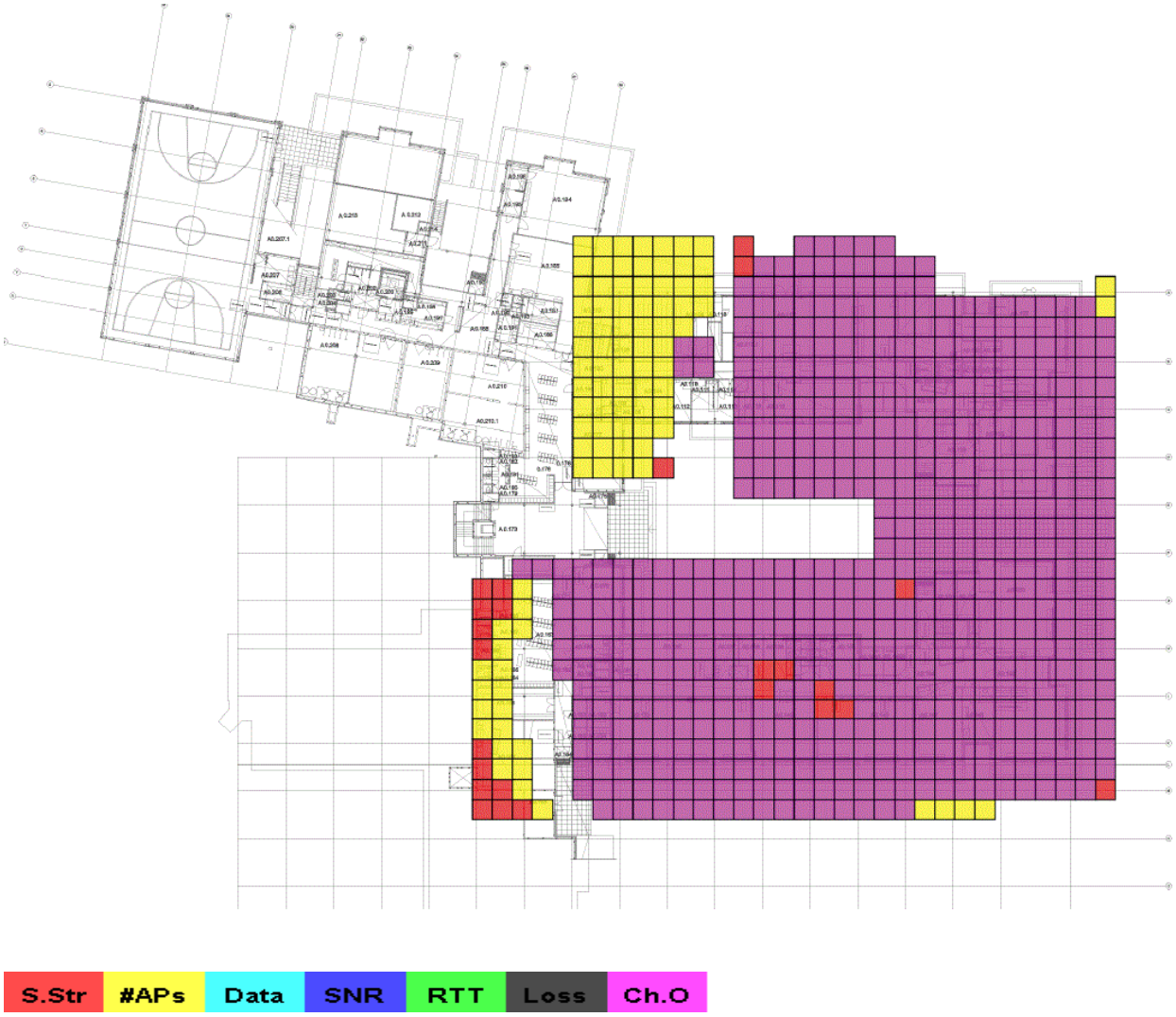


Figure 30. Network Issues for 2.4 GHz

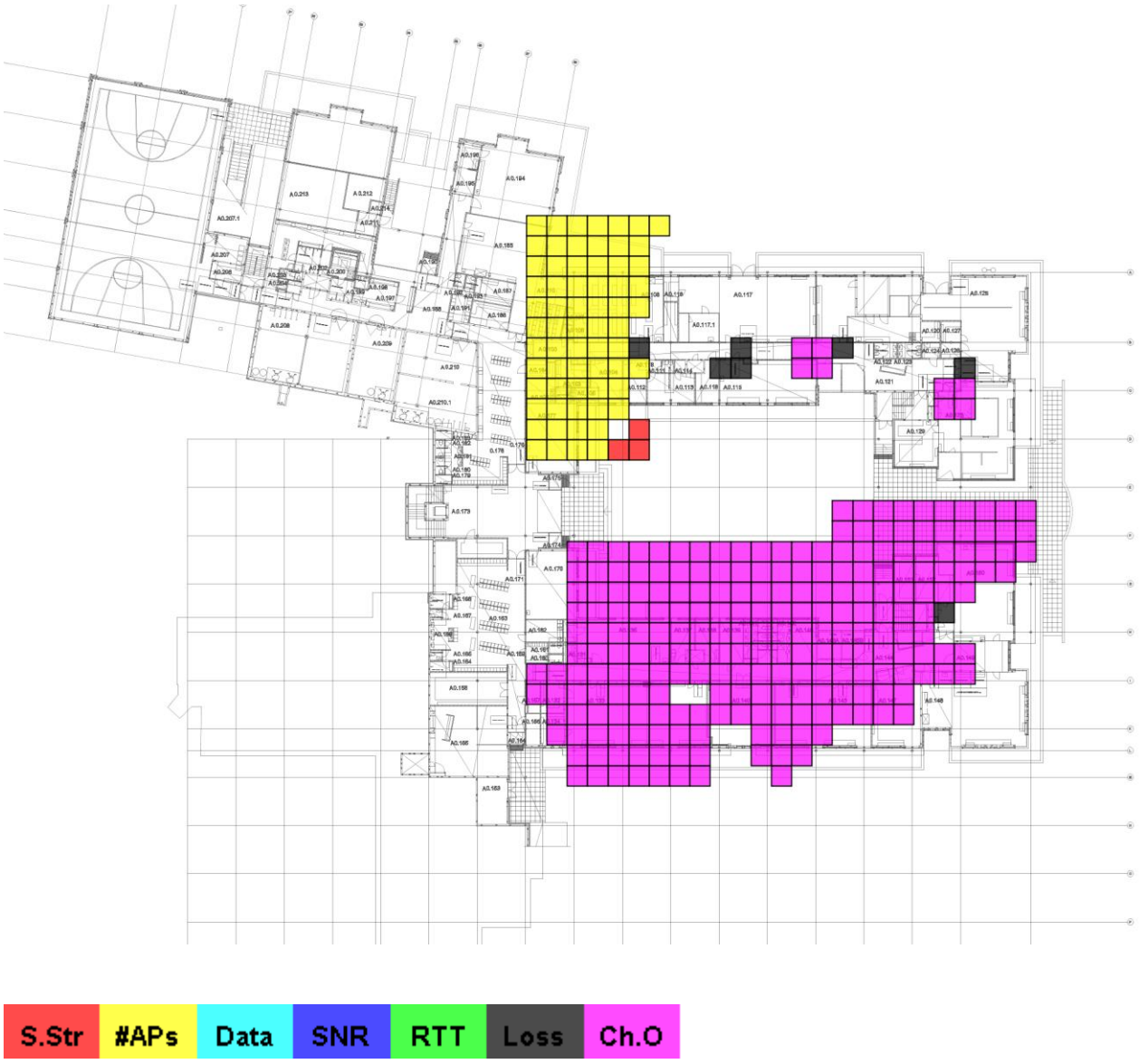


Figure 31. Network Issues for 5 GHz

6

6.1 Access Points

The list of all APs that have impacts in this surveyed area is represented in this part. Since there are too many APs that may affect this area, only the list of APs, which are placed on this area is provided in this part. Other APs, for example APs of people who used their laptops or mobiles to broadcast their own WIFI signal are not highly emphasized. This is because these devices only operate in different hours of the day and more importantly, those APs are not under the school administration. It can be clearly seen from the list below that there are nine APs under the school's administrative control, that are placed in this surveyed area.

	802.11n	36	0c:68:03:4c:fa:29	mediatek
	802.11n	36	0c:68:03:4c:fa:2e	metropolia-guest
	802.11n	36	0c:68:03:4c:fa:2f	eduroam
	802.11n	36	0c:68:03:4c:fa:2a	metropolia-secure
	802.11n	36	0c:68:03:4c:fa:2d	unigames
	802.11n	36	0c:68:03:4c:fa:28	tietotekniikka-lab
13	Cisco: ety-a0133-2702i			
	802.11n	1	cc:46:d6:b7:27:61	metropolia-guest
	802.11n	1	cc:46:d6:b7:27:66	mediatek
	802.11n	1	cc:46:d6:b7:27:65	metropolia-secure
	802.11n	1	cc:46:d6:b7:27:67	tietotekniikka-lab
	802.11n	1	cc:46:d6:b7:27:60	eduroam
	802.11n	1	cc:46:d6:b7:27:62	unigames
	802.11ac	36	cc:46:d6:b7:27:6a	metropolia-secure
	802.11ac	36	cc:46:d6:b7:27:6e	metropolia-guest
	802.11ac	36	cc:46:d6:b7:27:6d	unigames
	802.11ac	36	cc:46:d6:b7:27:69	mediatek
	802.11ac	36	cc:46:d6:b7:27:6f	eduroam
	802.11ac	36	cc:46:d6:b7:27:68	tietotekniikka-lab
14	Cisco: ety-a0134-2602i			
	802.11n	6	20:bb:c0:3a:5d:21	metropolia-guest
	802.11n	6	20:bb:c0:3a:5d:22	unigames
	802.11n	6	20:bb:c0:3a:5d:20	eduroam
	802.11n	6	20:bb:c0:3a:5d:27	tietotekniikka-lab
	802.11n	6	20:bb:c0:3a:5d:26	mediatek
	802.11n	6	20:bb:c0:3a:5d:25	metropolia-secure
	802.11n	48	20:bb:c0:3a:5d:2d	unigames
	802.11n	48	20:bb:c0:3a:5d:2a	metropolia-secure
	802.11n	48	20:bb:c0:3a:5d:29	mediatek
	802.11n	48	20:bb:c0:3a:5d:2f	eduroam
	802.11n	48	20:bb:c0:3a:5d:2e	metropolia-guest
	802.11n	48	20:bb:c0:3a:5d:28	tietotekniikka-lab
15	Cisco: ety-a0143-2602i			
	802.11n	1	20:bb:c0:3a:60:85	metropolia-secure
	802.11n	1	20:bb:c0:3a:60:82	unigames
	802.11n	1	20:bb:c0:3a:60:86	mediatek
	802.11n	1	20:bb:c0:3a:60:81	metropolia-guest
	802.11n	1	20:bb:c0:3a:60:80	eduroam
	802.11n	1	20:bb:c0:3a:60:87	tietotekniikka-lab
	802.11n	44	20:bb:c0:3a:60:89	mediatek
	802.11n	44	20:bb:c0:3a:60:8a	metropolia-secure
	802.11n	44	20:bb:c0:3a:60:8d	unigames
	802.11n	44	20:bb:c0:3a:60:8f	eduroam
	802.11n	44	20:bb:c0:3a:60:88	tietotekniikka-lab
	802.11n	44	20:bb:c0:3a:60:8e	metropolia-guest

10	Cisco: ety-a0115-2702i			
	802.11n	1	ec:bd:1d:33:56:85	metropolia-secure
	802.11n	1	ec:bd:1d:33:56:86	mediatek
	802.11n	1	ec:bd:1d:33:56:81	metropolia-guest
	802.11n	1	ec:bd:1d:33:56:82	unigames
	802.11n	1	ec:bd:1d:33:56:80	eduroam
	802.11n	1	ec:bd:1d:33:56:87	tietotekniikka-lab
	802.11ac	64	ec:bd:1d:33:56:8a	metropolia-secure
	802.11ac	64	ec:bd:1d:33:56:88	tietotekniikka-lab
	802.11ac	64	ec:bd:1d:33:56:8d	unigames
	802.11ac	64	ec:bd:1d:33:56:8e	metropolia-guest
	802.11ac	64	ec:bd:1d:33:56:89	mediatek
	802.11ac	64	ec:bd:1d:33:56:8f	eduroam
11	Cisco: ety-a0121a-2602			
	802.11n	6	20:bb:c0:3a:5d:16	mediatek
	802.11n	6	20:bb:c0:3a:5d:15	metropolia-secure
	802.11n	6	20:bb:c0:3a:5d:10	eduroam
	802.11n	6	20:bb:c0:3a:5d:11	metropolia-guest
	802.11n	6	20:bb:c0:3a:5d:17	tietotekniikka-lab
	802.11n	6	20:bb:c0:3a:5d:12	unigames
	802.11n	40	20:bb:c0:3a:5d:1d	unigames
	802.11n	40	20:bb:c0:3a:5d:1e	metropolia-guest
	802.11n	40	20:bb:c0:3a:5d:18	tietotekniikka-lab
	802.11n	40	20:bb:c0:3a:5d:1f	eduroam
	802.11n	40	20:bb:c0:3a:5d:1a	metropolia-secure
	802.11n	40	20:bb:c0:3a:5d:19	mediatek
12	Cisco: ety-a0128-2602i			
	802.11n	1	0c:68:03:4c:fa:22	unigames
	802.11n	1	0c:68:03:4c:fa:26	mediatek
	802.11n	1	0c:68:03:4c:fa:21	metropolia-guest
	802.11n	1	0c:68:03:4c:fa:20	eduroam
	802.11n	1	0c:68:03:4c:fa:25	metropolia-secure
	802.11n	1	0c:68:03:4c:fa:27	tietotekniikka-lab

Figure 32. Access Points Table

As can be seen from the above table that on 5Ghz band, there are two APs that are running on the same channel 40. However, the two rooms - 0121 and 0148 are quite far from each other. Consequently, I t can be said that this kind of overlap channel on 5Ghz

band has no impact on the network performance. Since it is stated earlier, having too many APs in the same area may cause problems in network performance if the channel for each AP is not well planned. On 2.4Ghz band, currently there are too many Aps operating on channel 1 and the position of those APs are next to each other. It is commonly known that on 2.4Ghz band there are three non-overlapping channels, namely 1, 6 and 11 that APs should use for their network. It is also highly recommended that one AP should not operate at the same channel with its neighbor AP. But from the table above, most APs in this area are running on channel 1. Only some APs are working on channel 6 and none of the APs are operating on channel 11. This fact becomes critical since channel 1 is especially crowded while channel 11 is wasted. The simplest solution to the above problem is to re-plan the channels of all APs so that for the block of three neighbor APs, one should work on channel 1, one should go to channel 6 and the other should perform on channel 11. However, this is not an accurate method. To probably solve the overlapping problems, one should also notice that there are not only APs that are placed on this area but also, APs of different people and APs from different areas (other floors) which have impacts on this surveyed area. There are two methods to eliminate this problem. The first approach is simple. By using one spectrum analysis software, for example inSSIDer, to determine the least crowded channel for an area of one AP, administrator can configure that AP to operate on free channel. One drawback of this method is that it will take long time to finish this task because administrator will have to walk inside each room and run the software. The second solution takes advantages of one feature - called channel planning, on the Ekahau Site Survey(ESS) software. To accomplish this, administrator will have to perform the site survey using ESS software for the whole building. Then by using the automatic channel-planning, the administrator can use the recommend channel from the software to configure for the school’s AP.

6.2 Other Access Points

AP #	Access Point			
1				
	802.11n 802.11n	11 11	88:15:44:a8:27:06 8e:15:44:a8:27:06	Unknown SSID Unknown SSID
	802.11ac 802.11ac	40@80 40@80	8e:15:54:a8:27:06 8a:15:54:a8:27:06	Metropolia Meraki 2 Metropolia Meraki 1
2				
	802.11n 802.11n	1 1	8e:15:44:a8:27:ed 88:15:44:a8:27:ed	Unknown SSID Unknown SSID
	802.11ac 802.11ac	36@80 36@80	8e:15:54:a8:27:ed 8a:15:54:a8:27:ed	Metropolia Meraki 2 Metropolia Meraki 1
3				
	802.11n 802.11n	6 6	8e:15:44:a8:28:a9 88:15:44:a8:28:a9	Unknown SSID Unknown SSID
	802.11ac 802.11ac	40@80 40@80	8a:15:54:a8:28:a9 8e:15:54:a8:28:a9	Metropolia Meraki 1 Metropolia Meraki 2
4	Cisco: Lidar			
	802.11g	3	00:19:06:0d:86:d0	salaseura

Figure 33. Other Access Points Table

7 Conclusion

WLAN, which combines both computer technology and wireless communication technology is the answer to many Wi-Fi related problems. From the theory part of this project I was able to gain more information on the network standards, advantages and limitations of the WLAN technologies. ESS is one of the best solution to make the network infrastructure smarter and solve network related problem in this competitive world.

The goal of the project was to improve user experience on the campus with wireless network modeling by using the tool kit Ekahau Site Survey. ESS is being used by the global leading companies for network mapping, design and implementation of wireless network. Based on my experience in working life and this thesis I can confirm that ESS

tools accelerates and significantly enhance the design of wireless network, implementation and troubleshooting problems.

Because of this work, I discovered several shortcomings in the Leppävaara campus wireless LAN implementation. Based on the survey results, I can say that the network and the effectiveness of the base stations are not appropriately adjusted. The number of base stations in some locations was less to ensure the operation of the network in the event of equipment failure. Optimization of the wireless LAN is necessary for network access peaks, better operating and fault-free wireless network entity. Recommendation for Metropolia UAS administrators is that channel overlapping must be managed as soon as possible and cell sizes should be increased and few dead spots should be avoided to overcome the problems like crosstalk and network letdown.

Metropolia UAS is one of the technologically forward educational institutes in this country. Its emphasis is to provide best quality of services to all the staffs and students. All the network equipment is up to date and they meet the latest network standards.

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